INTERNATIONAL COMET QUARTERLY

Whole Number 136 OCTOBER 2005 Vol. 27, No. 4

— *Table of Contents* —

SMITHSONIAN ASTROPHYSICAL OBSERVATORY
60 Garden Street · Cambridge, MA 02138 · U.S.A.

The International Comet Quarterly (*ICQ*) is a journal devoted to news and observation of comets, published by the Smithsonian Astrophysical Observatory in Cambridge, Massachusetts. Regular issues are published 4 times per year (January, April, July, and October), with an annual *Comet Handbook* of ephemerides published normally in the first half of the year as a special fifth issue. An index to each volume normally is published in every other October issue (now in odd-numbered years); the *ICQ* is also indexed in *Astronomy and Astrophysics Abstracts* and in *Science Abstracts Section A*.

The regular (invoiced) subscription rate is US$40.00 per year for North American and for overseas surface-mail delivery (price includes the annual *Comet Handbook*; the price without the *Handbook* is US$30.00 per year). Subscribers who do not wish to be billed may subscribe at the special rate of US$30.00 per year for surface-mail delivery (rate is $20.00 without *Handbook*). Add $20.00/year to each of these rates for overseas airmail delivery. These rates became valid as of Sept. 2005. [The last set of digits (after the hyphen) on the top line of the mailing address label gives the Whole Number that signifies the last *ICQ* issue which will be sent under the current subscription status. An asterisk after these numbers indicates credit for the next annual Comet Handbook. The first five digits represent the subscriber's account number.] Make checks or money orders payable in U.S. funds (and drawn on a U.S. bank) to *International Comet Quarterly* and send to Mail Stop 18; Smithsonian Astrophysical Observatory; 60 Garden St.; Cambridge, MA 02138, U.S.A.

Credit cards may be used for payment of subscriptions, though a minimum of US$20.00 can be accepted for each charge. Credit-card orders may be placed by e-mail (to iausubs@cfa.harvard.edu), by fax (to USA 617-495-7231), or by telephone (to USA 617-495-7280, generally between 14:00 and 21:00 UT, Monday to Friday). When sending orders by fax or e-mail, please include the following information: (1) your name (as given on the credit card); (2) card type (MasterCard, Visa, or Discover); (3) credit-card number and expiration date; (4) address at which the card is registered; (5) which services you wish to subscribe to; (6) if the payment is for the renewal of a current or expired account, please include your account number.

Group subscription rates available upon request. Back issues are $10.00 each — *except* for "current" *Comet Handbooks*, which are available for $15.00 ($10.00 to subscribers if ordered with their *ICQ* subscription; see above). Up-to-date information concerning comet discoveries, orbital elements, and ephemerides can be obtained by subscribing to the *IAU Circulars* and/or the *Minor Planet Circulars* (via postal mail and also available via computer access); for further information, contact the above e-mail address (or the *ICQ* at the above postal address).

Manuscripts will be reviewed/refereed for possible publication; authors should first obtain a copy of "Information and Guidelines for Authors" from the *ICQ* website or from the Editor. Cometary observations should be sent to the Editor in Cambridge; again, see the *ICQ* website or contact the Editor for the proper format. Those who can send observational data (or manuscripts) in machine-readable form are encouraged to do so [especially through e-mail via the Internet (ICQ@CFA.HARVARD.EDU)]. The *ICQ* has extensive information for comet observers on the World Wide Web, including the Keys to Abbreviations used in data tabulation (see URL http://cfa-www.harvard.edu/icq/icq.html). In early 1997, the *ICQ* published a 225-page *Guide to Observing Comets*; this edition is now out of print, but a revised edition is under preparation.

Most of the Observation Coordinators (OCs) listed below have e-mail contacts with the *ICQ* Editor; observers in the general area of such OCs who lack access to e-mail networks may send data to the OC for relay to the *ICQ* in electronic form.

++++++++++++

This issue is No. 136 of the publication originally called *The Comet* (founded March 1973) and is Vol. 27, No. 4, of the *ICQ*. *[ISSN 0736-6922]*

****

FROM THE EDITOR

The new Directorship of the Harvard-Smithsonian Center for Astrophysics has decreed (only recently, with little notice) that, as of 2005 Nov. 15, the SAO print shop will be closed down. The fine work done by Bill Duggan and Dan Collins there to print the *ICQ* for the past 1.5 decades will be sorely missed. Readers are warned that the January 2006 issue could be somewhat delayed as a transfer to a new printing process could take much time and effort.

Comet 73P/Schwassmann-Wachmann: Nucleus Fragmentation, Its Light-Curve Signature, and Close Approach to Earth in 2006

Zdenek Sekanina
Jet Propulsion Laboratory; California Institute of Technology; Pasadena, CA 91109; U.S.A.

Abstract. *The history of observation of comet 73P is described, and the remarkable 1995 apparition (during which the nucleus split into a large number of fragments) is highlighted. The primary breakup event was accompanied by an enormous outburst at optical and radio wavelengths. The principal fragment and two surviving companions were observed as recently as 2000. The comet's very favorable return to the sun in 2006 offers an opportunity to search for these still-possibly-existing minor fragments of the original nucleus. One of this paper's objectives is to facilitate such an endeavor by providing a search ephemeris.*

1. Introduction

Cascading fragmentation is increasingly perceived as the dominant process of cometary extinction. This suggests that genuine disintegration of the original cometary nucleus, rather than its progressive deactivation and/or gradual sublimation, accounts in most cases for the object's end state. For comets that closely approach the sun, the fragmentation process is accompanied or followed by potentially significant, heliocentric-distance-dependent nucleus erosion. Although the mechanism is unknown, fragmentation appears to be essentially spontaneous, is usually nontidal, and could be facilitated by extremely low cohesion of cometary nuclei, with rotational and thermal stresses believed to play a role. Comets may and often do split more than once and over a number of revolutions about the sun. Unfortunately, little is known about the disintegration rate, the number of fragmentation steps and fragment generations, the size distribution of fragments as a function of time, and the temporal scales involved, which may vary significantly from case to case. As fragmentation products grow ever smaller and fainter with time, the flow of information is constrained by the detection threshold. Since this limit depends, besides instrumentation, on the observer's distance, great strides in the understanding of the process can be achieved during the earth's close encounters with comets that are known to have split.

An important property of split comets is brightness fluctuation of their fragments, which reflects irregular variations of their activity with time. It is not unusual for some of thee fragments to become temporarily undetected only to reappear later. A fragment's life span depends not only on its size, but also on its cohesion and physical behavior. Persistent fragments of periodic comets may survive for two or more revolutions about the sun, with the primary nucleus (the most massive fragment) often continuing to orbit the sun as if unaffected by the fragmentation events. On the other hand, in extreme cases all fragments may disintegrate catastrophically on a time scale of only a few weeks or so following a fatal fragmentation event, with the comet literally ceasing to exist. Investigations of the physical evolution of individual fragments of a split comet contribute significantly to our understanding of the fragmentation process.

Because of brightness fluctuations and gaps in observing a split comet (due to unfavorable observing conditions resulting from a changing projection geometry), it may become very difficult or impossible to identify the fragments over long periods of time without applying a sophisticated model that is capable of determining the most probable scenario for the comet's fragmentation sequence and hierarchy.

There are numerous documented cases of a close temporal relationship between a fragmentation event experienced by a comet and its outburst or flare-up. Both phenomena are likely to be inextricable products of suddenly increased activity, with the companion nucleus representing in fact the largest "particle" in the cloud of emerging dust ejecta.

In this paper, I apply the concept of cascading fragmentation to investigate the orbital evolution of the nucleus of comet 73P/Schwassmann-Wachmann, which split into a number of pieces in 1995, which has a very favorable return to the sun in 2006, and which was very recently recovered (Green 2005). As a necessary preparatory step for establishing the fragmentation sequence and hierarchy of companion nuclei, I first derive the comet's composite light curve by exploring all information available on its brightness since discovery. I then focus on the more extensively observed nucleus fragments, present a set of their most probable birth scenarios, and examine their potential relationship to the enormous outburst that the comet is known to have experienced in 1995. Finally, I provide search ephemerides for several potentially surviving nucleus fragments during this return, thus assisting observers in their efforts to recover as many nucleus fragments as possible. These predictions should also benefit a wide range of other comet science endeavors, including activities aimed at radar detection and scrutiny of the nucleus fragments and, more generally, offer information critical to future robotic exploration of comets and their nucleus environment.

2. The Observation History of Comet 73P

Comet 73P is a member of the Jupiter family of short-period comets, making one revolution about the sun in 5.4 years and currently reaching 0.94 AU from the sun at perihelion. This is the comet's sixth observed return. Its history makes 73P one of the best candidates for studies of cascading fragmentation.

Discovered in 1930, when it approached Earth to 0.062 AU on May 31, the comet was observed fairly extensively for nearly four months. Yet it was missed at the subsequent returns to the sun and eventually lost. It remained unobserved until 1979, when it arrived at perihelion five weeks later than predicted (the orbital error apparently amplified by a close approach to Jupiter in 1965), was picked up as a new comet by J. Johnston and M. Buhagiar at Perth (Candy 1979; Marsden 1984), and remained under observation for three months. Missed again during the unfavorable return of 1985, it was followed extensively in 1990 and especially in 1995. More recently, the comet was detected beyond 3 AU from the sun in March-April 2000 (Boehnhardt et al. 2002) and, remarkably, at elongations smaller than 27° from the sun in November and December 2000 (Marsden 2000, 2001) during the utterly unfavorable return to perihelion in early 2001. Before its 2005 recovery (Green 2005), the comet had last been seen in mid-December 2001.

The comet's physical aspect during the discovery apparition was of major interest, because the object was widely observed to have a double-tail appearance in May 1930, reminiscent of a spindle or a spiral nebula seen edgewise (*e.g.*, Van Biesbroeck 1930, Beyer 1931). Sekanina (1989) showed that the extension pointing away from the sun (which was not seen in June and July 1930) was a regular tail, while the broader and usually shorter appendage — reported also after perihelion (Dartayet 1931, Hartmann 1931) — was a sunward emission fan, providing information on the surface location of an active region responsible for the dust-ejecta anisotropy and on the nucleus spin-vector position. Sekanina's modeling of the fan-orientation variations with time led him to conclude that the nucleus was precessing, its rotation axis describing an angle of ~ 90° over a period of three months. The active region extended up to about 20° from the rotation pole and its area was estimated at 0.8 km^2.

The truly exciting apparition was that of 1995, when the comet underwent a huge outburst (Sec. 3) and, several months later, a multiple nucleus was observed for the first time (Sec. 4). Astrometric observations of two or more nucleus fragments were made during much of 1996, interrupted only by the comet's conjunction with the sun, and again in 2000 and 2001. No comprehensive investigation of this comet's fragmentation has ever been published.

The 2006 return to the sun offers an exceptional opportunity to search for the nucleus fragments observed in the past as well as for products of possible additional, more-recent fragmentation events that we are as yet unaware of. The return is almost as favorable as that of 1930, with the main comet predicted to approach Earth to 0.0787 AU, or 11.8 million km, on 2006 May 12.4 TT. This close encounter will allow observers with big telescopes to detect inert fragments as small as 80 meters across — and even smaller ones if they still show signs of activity. However, such detections — of apparent magnitude, say, 21-22 — will only be possible if a search ephemeris pinpointing their locations is available. In 2001, the differences in perihelion times among the nuclei reached up to more than ~ 0.7 day (*e.g.*, Nakano 2000), which by 2006 are expected to increase to much more than 1 day (*e.g.*, Nakano and Marsden 2003a, 2003b), equivalent to separations of up to at least ~ 4 million km along the orbit. At the earth's distance of ~ 12 million km, such separations will project as more than 20° in the sky. A dependable ephemeris will indeed be absolutely indispensable.

3. The Composite Light Curve

No comprehensive study of the history of the light curve for comet 73P has ever been published, although the huge 1995 outburst would itself seem to justify such an effort. The highly favorable 2006 return to the sun adds more urgency to it.

Data on the integrated brightness of comet 73P have been reported from each of the observed returns to the sun. Previously I analyzed the comet's light curve from 1930 (Sekanina 1989) by examining a total of 44 visual magnitude estimates made by 10 observers (or observer groups), mostly around the time of closest approach to Earth. (The paper lists all references to the original sources.) When normalized to 1 AU from Earth by an inverse-square power law, the estimates appeared utterly discordant in spite of an introduction of personal/instrument corrections (see below). It appeared that some 1930 observers saw the comet brightening on its way to perihelion, while others fading. The culprit was obviously the "delta effect" brought about by the human eye's inability to detect faint outer fringes of a very extended object of an exceptionally low surface-brightness gradient. More recently I re-examined an augmented 1930 set of 63 mostly visual magnitudes using an inverse-first-power law, as proposed long ago by Öpik (1963), and was surprised to find that 80 percent of 55 data points by 15 observers with two or more published observations now became consistent with one another. In addition, the resulting light curve conformed to the light curves from the 1979 and 1990 apparitions and to the pre-outburst light curve from 1995, even though the comet's perihelion distance in 1930 was 0.07-0.08 AU greater. This is shown in Figure 1 by the solid curve attaining normalized magnitude H_Δ (at 1 AU from Earth) of 10.0 at perihelion and marked 1930-1995 prior to perihelion and 1930-1990 after perihelion.

The magnitude observations reported since 1979, nearly all of which were taken from the *International Comet Quarterly (ICQ)*, were normalized to 1 AU from Earth with an inverse-square power law. The data reduction then followed a standard procedure, which, to the extent possible, corrected for personal and instrumental effects of observers. Their temporally overlapping individual light curves were visually compared and the scatter among them minimized by shifting them along the magnitude axis until the best match was in each case achieved. Time gaps between any two

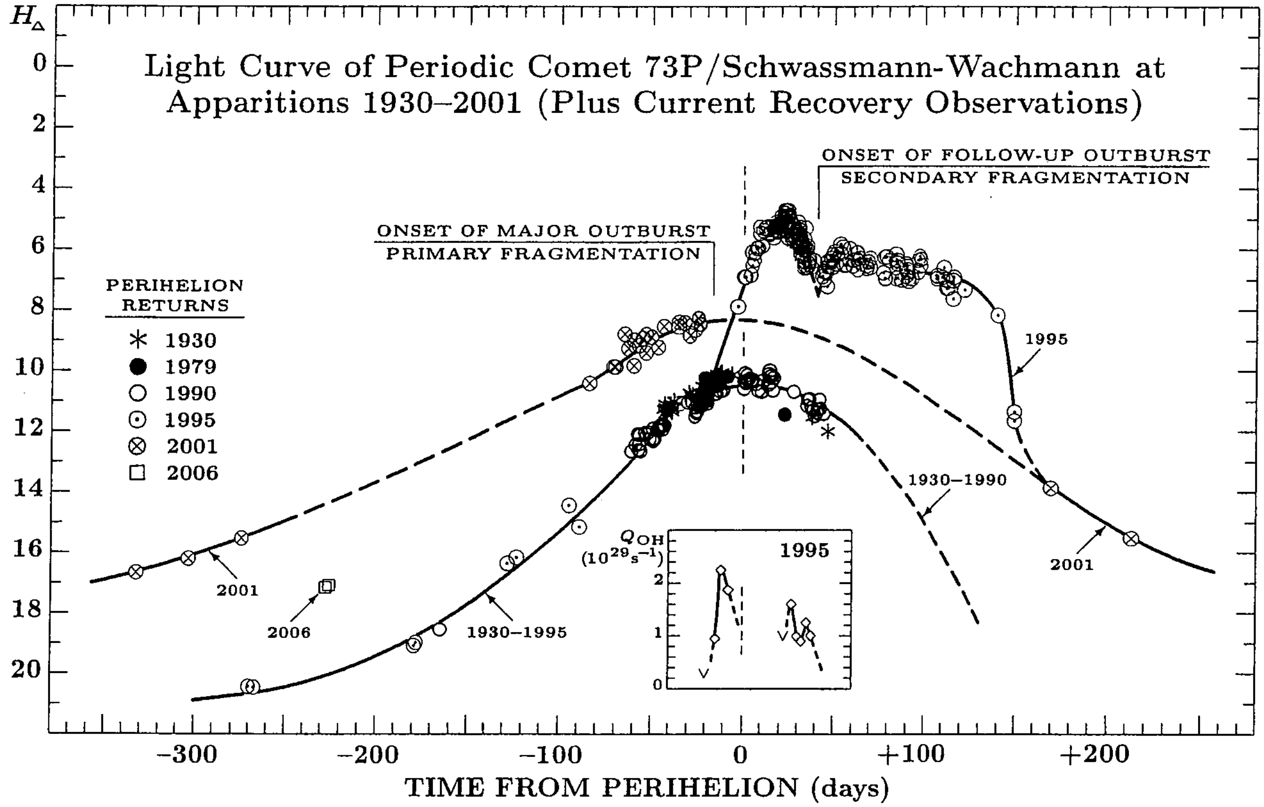


Figure 1. Visual light curve of comet 73P at the apparitions of 1930, 1979, 1990, 1995, and 2001. In 1930, the comet's perihelion distance was $q = 1.01$ AU; between 1979 and 2001, $q = 0.93$-0.94 AU. The onset times of the two outbursts in 1995 and their apparent coincidence with the times of primary- and secondary-nucleus fragmentation are marked. The 1995 perihelion occurred on September 22.9 TT. The inset depicts the parallel temporal variations in the hydroxyl production rate, measured by Crovisier et al. (1996).

◇ ◇ ◇

[text continued from page 226]

such light curves were spanned by additional data points provided by other observers. In this trial-and-error fashion, constant corrections were determined for the data sets that were reasonably uniform and the normalized magnitudes then converted to a common visual photometric system. The CCD magnitudes were corrected for a color index, when not measured in the visual system. The same observers with the same instruments were assigned the same corrections at all apparitions, which were thus dealt with independent of one another. The total number of data points employed in the light curve in Figure 1 amounts to 44 from 1930, 8 from 1979, 107 from 1990, 210 from 1995, and 26 from 2001.

The astonishing 1995 outburst began some 16 days before perihelion, on September 6-7. It was first detected with the Nançay Radio Telescope by Crovisier *et al.* (1996), whose results are shown in the inset of Figure 1. The comet's integrated signal in OH at 18 cm was below the detection limit in their run from September 1 to 5 (21 to 17 days before perihelion), but was clearly present in runs during September 8-10 (14 to 12 days before perihelion), 11-13, and 14-18. The peak OH production rate, apparently occurring on September 13 (Crovisier *et al.* 1995), was at least 10σ. The comet was next observed in the second half of October, when the signal was somewhat variable, corresponding on the average to a production rate of about half the peak September value.

Optically, the outburst was first detected on September 17-21 (Green 1996a), when the comet was at least 4 magnitudes more luminous than a month earlier; by October 9-10, the comet was brighter than apparent magnitude 6 (Green 1996b). As large amounts of dust ejecta continued to accumulate in the growing coma, the comet's brightness kept increasing for as long as 36 days, until October 12-13 or so. In an early phase of the outburst, the rate of brightening was approximately constant on the magnitude scale [and therefore exponential(!) on the brightness scale], amounting to $\sim$ 0.2 mag/day, so that the comet was 1.2 times as bright at the end of the day as it had been at its beginning. The amplitude, measured as a difference between the normalized magnitudes at the onset and the peak, was fully 5 magnitudes. In mid-October the brightness leveled off and then started to fall, reaching apparent magnitude 8 in late October and early November, when a new upturn occurred about 41 days after perihelion. Calling it a follow-up outburst in Figure 1, I found that the rise time of this event was about two weeks and the amplitude some 1.4 magnitudes. As a result, the apparent visual magnitude was back to 7 in mid-November and the subsequent descent was very slow, at a rate of approximately 0.01 mag/day, a remarkably gradual development continuing for at least 10 weeks. An accelerated

TABLE 1
OUTBURSTS OF COMET 73P/SCHWASSMANN-WACHMANN IN 1995.

Outburst	Time t_0 of onset[a] 1995 (UT)	t_0-T (d)	Rise time (d)	Brightness amplitude (mag)	Normalized magnitude at onset	at peak
Major	Sept. 6.9	−16 ± 3	36 ± 4	5.0 ± 0.5	10.2 ± 0.4	5.2 ± 0.3
Follow-up	Nov. 2.9	+41 ± 1	14 ± 5	1.4 ± 0.3	7.5 ± 0.2	6.1 ± 0.2

[a] Date and time from perihelion passage T (minus sign = preperihelion, plus sign = postperihelion).

◇ ◇ ◇

[text continued from page 227]

drop in brightness did not commence until 18-19 weeks after perihelion and is rather poorly documented by very few observations. The parameters of the two outbursts are summarized in Table 1.

There are no total-magnitude data available from the end of February 1996 on, when the comet headed into a conjunction with the sun. C. Hergenrother's post-conjunction observations from 1996 September 20 and 21 (Green 1997) showed the comet at heliocentric distance $r = 3.6$ AU to be, on the average, only 0.3 magnitude brighter intrinsically at the same phase angle than Boehnhardt *et al.*'s (1999) pre-perihelion observations during 1994 December 27-30 at $r = 3.0$ AU, when compared using an inverse-square law. (Hergenrother's data points are way outside the margins of Figure 1, at a time of more than 360 days after perihelion.) It was therefore unclear, at that point, whether the comet was still in an excited state following the 1995 outbursts. This question was answered four years later when, some 300 days before perihelion, the object was detected independently by A. Nakamura, T. Oribe, and Hergenrother (Green 2000a) about 4 magnitudes brighter than during the previous return to the sun and brightening with decreasing heliocentric distance more rapidly than predicted by the inverse-square power law. Later, several weeks before perihelion, the normalized brightness was still about 2 magnitudes above the pre-outburst level of 1995. Unfortunately, during the exceedingly unfavorable 2001 apparition, the comet's brightness was estimated over a period of only 55 days before perihelion. Two additional observations made, respectively, by K. Kadota and by Nakamura (Green 2001) about 200 days after perihelion showed it to be intrinsically fainter than its interpolated brightness at the same heliocentric distance before perihelion, but still much brighter than on its approach to the sun in 1995. Hergenrother's 2005 recovery data (Green 2005), converted to visual magnitudes in Figure 1, suggest a further drop since the 2001 return to only a moderately elevated level relative to the pre-outburst light curve. A bare principal-nucleus fragment, presumably < 2 km in diameter (based on Boehnhardt *et al.*'s 1999 result that the parent nucleus was < 2.2 km across), should in late October 2005 be fainter than apparent magnitude 22.

4. Discovery and Evolution of Nucleus Multiplicity

The multiplicity of the comet's nucleus was first detected by Boehnhardt and Käufl (1995) at the European Southern Observatory's (ESO) La Silla station in Chile during their observing run of 1995 December 12-14. The observations were made simultaneously with the 3.5-meter New Technology Telescope in the optical wavelength range and with the 3.6-meter telescope in the thermal infrared. The three optically detected fragments were aligned in a nearly rectilinear chain about 4″ long and oriented approximately along the projected direction of the sun. Based on the notation used by Marsden (1996), the westernmost of the three condensations became known as *A*, the easternmost as *C*, and the middle, initially the faintest one, as *B*. For clarity, I use italics to refer to the fragment designations in published accounts to distinguish them from the designations based on the results of this work, for which I will employ roman letters.

Next, the ESO images of the comet taken up to two weeks before the discovery of the nucleus multiplicity, by K. Reinsch on November 28 and by J. Storm on December 2, were processed and closely inspected by Boehnhardt *et al.* (1996), and the elongated central condensation was resolved into two components. The second component in these images was attributed to fragment *B*, but it could have been *A* as well (Sekanina *et al.* 1996).

Subsequent observations clearly indicated that *C* was the main, most-massive fragment. From 1995 December 23 on, the multiple nucleus was noticed at several observatories worldwide. Besides the three major condensations, additional companions were reported, but none of these was detected by more than one group and they all have remained unconfirmed. J. V. Scotti measured a condensation, officially designated *D* (Marsden 1996), less than 2″ to the east-northeast of *C* on December 27. Three more condensations detected by others between 1995 December 12 and 1996 January 21 have not received formal designations.

Nuclei *A*, *B*, and *C* were seen until mid-February 1996, after which time the comet was too close to the sun for observation. After conjunction with the sun, the comet was picked up in the second half of August 1996, when only two condensations were detected. Tentative identifications indicated that — besides the main nucleus *C* — the only companion visible was *B*. Both were observed by various observers until nearly the end of 1996.

When the comet was recovered on its way to the next perihelion passage, in the second half of November 2000, three widely separated condensations were observed; besides *C*, one of the companions was tentatively identified with *B*, while

TABLE 2
ASTROMETRIC DATA SUBSETS FOR COMPANION FRAGMENTS OF COMET 73P/SCHWASSMANN-WACHMANN.

Data subset	Time span (UT)	Separation distances from nucleus C[a]	Number of collected data points	Fragment identity		Companion relative to nucleus C[a]
				published	this work	
I	1995 Nov. 28–1996 Feb. 16	1–9″	45	*B*	B	closer
II	1995 Dec. 12–1996 Feb. 19	3–22″	67	*A*	A	more distant
III	1996 Aug. 22–1996 Dec. 14	17–25″	14	*B*	E[b]	
IV	2000 Nov. 19–2000 Dec. 29	468–651″	23	*B*	F	closer
V	2000 Nov. 28–2000 Dec. 20	1409–1704″	34	*E*	E	more distant
VI	2001 Jun. 18–2001 Dec. 10	132–198″	15	*B*	F	

[a] C and *C* always referrring to the same fragment.

[b] Nucleus B nearly coinciding with E.

◇ ◇ ◇

[text continued from page 228]

the other, not fitting *A*, was officially designated *E*, as a new fragment (Green 2000b). After perihelion, which occurred near the end of January 2001, two condensations — *C* and what was considered a likely candidate for *B* (Boehnhardt *et al.* 2002) — were under observation at ESO during the second half of 2001 until December 10. No known additional images have been obtained since (again, as of mid-October 2005).

The astrometric positions of the companion fragments relative to the principal nucleus *C* (a separation distance and a position angle or offsets in right ascension and declination) that I collected for this investigation totaled 198 sets. Their summary is in Table 2: The entire data set is divided into six subsets by fragment and/or by major gaps in the temporal distribution of observations. The columns are self-explanatory, except for the difference between columns 5 and 6. Column 5, with the fragment identifiers in italics, refers to the published designations. Column 6 uses roman letters and lists the fragment identifiers resulting from this investigation. For three of the six subsets, the identifiers differ.

5. Fragmentation Sequence and Hierarchy

Most astrometric observations summarized in Table 2 were made with large telescopes, some even with the ESO's Very Large Telescope. Except in cases when a fragment was only poorly condensed (and therefore hard to measure), the collected positions should be quite accurate, mostly better than ± 1″. A dependable model is thus expected to fit the observations, spanning 6 years, to better than this limit and to leave no systematic trends in the residuals. In addition, the model is also expected to provide a useful ephemeris for 2006 — that is, at a time almost 5 years after the last observation of any of the companion fragments.

5.1. The Fragmentation Model. The only computer code for modeling a sequence and hierarchy of a split comet that was extensively tested on a large number of cases is the author's multiparameter fragmentation model (Sekanina 1978, 1982). By fitting the motion of a companion fragment relative to the principal (the most massive and persistent) nucleus, the model allows the user to determine, by an iterative, least-squares, differential-correction procedure, up to five parameters: the time of fragmentation (or separation); the companion's differential nongravitational deceleration (which, expressed in units of 10^{-5} of the sun's gravitational acceleration, is assumed to act continuously between the times of separation and observation and to vary as the inverse square of heliocentric distance); and three components of the companion's separation velocity, which point along the cardinal directions defined by the right-handed 'RTN' coordinate system of the heliocentric orbit of the parent comet: the radial axis (away from the sun), the transverse axis (in the orbital plane ahead of the comet), and the normal axis (to the orbital pole from which the comet is seen to orbit the sun counterclockwise). The mutual gravitational attraction of fragments was neglected.

When the identity of the primary fragment is not in doubt, such as in the case of comet 73P, meaningful solutions for companion fragments are expected to yield positive decelerations. Of considerable assistance is an option provided by the employed model to solve for any combination of fewer than the five parameters, so that a total of 31 different versions of the code are available. This option proves most beneficial in the early phases of the iterative process, before the solution settles around the optimum parametric values, or when the convergence is slow. The differential planetary perturbations and the relativistic effect acting on the fragments' motions are accounted for in the applied-code version, which was more recently developed in a joint effort by the author and P. W. Chodas and for the first time used in analysis of comet D/1993 F2 (Shoemaker-Levy), which split and later collided with Jupiter (Sekanina *et al.* 1998).

Since the fragmentation model provided an optimized fit to astrometric offsets of companion nuclei from the principal nucleus C = *C*, a set of orbital elements for this reference object was required as input. Although fragmentation solutions are generally not very sensitive to the orbit's accuracy, I carefully selected the set of elements for these model calculations.

TABLE 3

PREDICTED ORBITS FOR THE PRINCIPAL NUCLEUS OF COMET 73P/SCHWASSMANN-WACHMANN AT ITS 2006 RETURN TO THE SUN (OSCULATION EPOCH 2006 MAY 25.0 TT; EQUINOX J2000.0)

Orbital element	Orbit NEW	Orbit JPL	Orbit NAK	Orbit MUR
Perihelion time T (2006 TT)	June 6.9497	June 7.1718	June 7.3766	June 6.9225
Argument of perihelion ω	198°.8039	198°.8052	198°.8088	198°.8083
Longitude of ascending node Ω	69°.8955	69°.8958	69°.8941	69°.8959
Orbital inclination i	11°.3960	11°.3963	11°.3970	11°.3957
Perihelion distance q (AU)	0.939135	0.939141	0.939164	0.939121
Orbital eccentricity e	0.693192	0.693232	0.693257	0.693214
Orbital period P (yr)	5.36	5.36	5.36	5.36
Nongravitational parameters:				
A_1 (10^{-8} AU/day^2)	+1.33	+0.9848	+0.831	+0.65
A_2 (10^{-8} AU/day^2)	−0.0520	+0.0692	+0.1791	−0.0681
A_3 (10^{-8} AU/day^2)	......	−0.0721	−0.19	......
Closest approach to Earth:				
Predicted time (2006 TT)	May 12.4	May 12.8	May 13.2	May 12.4
Predicted distance (AU)	0.0787	0.0760	0.0735	0.0791
Predicted distance (mil. km)	11.8	11.4	11.0	11.8
Number of observations used	224	358	343	226
Observations linked	1995–2005	1994–2001	1989–2001	1994–2000
RMS residual	±0″.7	±0″.84	±0″.95	±0″.83
Orbital elements by	B. G. Marsden[a]	M. S. W. Keesey[b]	S. Nakano[c]	K. Muraoka[d]

[a] See Green (2005); only post-outburst 1995 observations of nucleus C included (Marsden 2005, personal communication).

[b] See http://ssd.jpl.nasa.gov/cgi-bin/da_shm?rec=900445; Keesey (2005, personal communication). Motion integrated from osculation epoch 2001 Nov. 27.

[c] See Marsden (2003a); Nakano and Green (2004).

[d] See http://www.aerth.net/comet/catalog/0073P/2001.html. Motion integrated from osculation epoch 2001 Jan. 11.

◇ ◇ ◇

[text continued from page 229]

Three of the options that I had are listed as orbits 'JPL', 'NAK', and 'MUR' in Table 3, in which the motion of the principal fragment was in each case integrated to a common near-perihelion osculation epoch in 2006 to allow comparison of the available orbital sets with Marsden's NEW set, which employs the 2006 recovery observations (Green 2005) but which did not exist at the time of my model calculations. Two of the three available sets are based on astrometric observations from the apparitions 1995 and 2001 (orbits denoted 'JPL' and 'MUR'), while the third was obtained by linking the data from the apparitions 1990, 1995, and 2001 (orbit denoted 'NAK'). Under ordinary circumstances, the three-apparition solution would clearly be preferable, but the point of much concern with this run was the linkage of the motion of the parent nucleus between 1989 and September 1995 with the motion of the principal fragment during the subsequent revolution about the sun. Momentum changes that this fragment was likely to experience during the 1995 fragmentation events could significantly affect any hybrid solution based on approximately equal contributions from the parent nucleus and the fragment. These concerns reached alarming proportions when I learnt of M. S. W. Keesey's (2005, personal communication) experience with a similar solution, which included the observations from 2000, but not 2001. Keesey says that this solution left systematic residuals of up to 2″.5 in 1989 and smaller ones in 1994-1995. However, when he added the 2001 data, no observations between February 1996 and April 2000 could be fitted, leaving residuals of up to 11″. Since this 1989-2001 orbit included the third nongravitational parameter (Keesey 2005, personal communication), the NAK solution (Nakano and Marsden 2003a, Nakano and Green 2004) must be subjected to the same, if not greater, difficulties. Comparison with the NEW set of elements shows that the 1994-2000/2001 solutions are indeed superior to the 1989-2001 solution.

As for the two-apparition runs (1994-2001), Keesey says that he began with a gravitational solution, which turned out to be utterly unacceptable, leaving systematic residuals of up to 16″ in 1994-1995 and up to 30″ in 2001. These findings justified his introduction of nongravitational parameters into the equations of motion. Keesey indeed found that the resulting solution (JPL) was then entirely satisfactory.

The two-apparition solutions in Table 3 appeared to represent preferable orbital determinations for the principal fragment because of their relatively minor contamination by observations of the parent nucleus. The orbital arc covered by the parent data was only 8.5 months, compared to nearly 6 years for the three-apparition runs. Since Muraoka's solution does not include the 2001 observations and is based on a substantially smaller data set, I decided to use the JPL solution in modeling the fragmentation process of 73P.

5.2. Fragment B. To start with, I assumed that B = *B*, implying that subsets I, III, IV, and VI in Table 2 all referred to the same companion fragment. Iteration of all five parameters failed to yield a converging solution. I then forced the time of fragmentation and solved for the remaining four parameters. When the breakup event was assumed to have coincided with the onset of the major outburst, the solution converged, but the results were unsatisfactory. The deceleration came out to be negative (-1.87 ± 0.46 units of 10^{-5} the sun's gravitational acceleration), the root-mean-square (RMS) residual was unacceptably large ($\pm$ $1''.66$), and the residuals displayed strong systematic trends of up to $1''$ in 1995, up to $3''$ in 1996 and 2000, and in excess of $3''$ in 2001. When the fragmentation time was forced to coincide with the onset time of the follow-up outburst, the results were clearly worse, with an RMS residual of $\pm$ $2''.05$ and systematic residuals in excess of $5''$ in 2001.

Linking only subsets I, IV, and VI likewise failed to lead to an acceptable solution, with the deceleration again negative, the RMS residual $\pm$ $1''.07$, and the systematic residuals now exceeding $1''$ in 1995 and early 1996 and up to $4''$ in 2001. Forcing the time of fragmentation did not improve the situation.

More experimentation with three subsets led to further disappointing solutions and to convergence problems. For example, linking only sets I, III, and VI and forcing the fragmentation time to coincide with the major outburst's onset time yielded an RMS residual $\pm$ $0''.84$ and systematic residuals of up to $6''$. Particularly disturbing was the inconsistency between the July and December 2001 positions, common to all described runs.

Linking only two subsets, I first chose I and VI. The best, although still rather unsatisfactory, solution was obtained by forcing the fragmentation time to coincide with the onset time of the follow-up outburst. The RMS residual was then $\pm$ $0''.74$, the deceleration 3.45 ± 0.60 units, and the systematic residuals up to $2''$. The five-parameter solution did not converge, and other solutions were less satisfactory than the described one.

Still-better solutions resulted from a linkage of subsets I and III. Even though the five-parameter version did not converge, it indicated an RMS residual near $\pm$ $0''.33$ and very slight systematic residuals of $< 1''$ primarily in August-December 1996. When the fragmentation time was approximated by the onset time of the major outburst, the solution was better (though not perfect) than when the follow-up outburst was used instead.

Subset I alone left a very satisfactory RMS residual of $\pm$ $0''.20$ with no systematic trends but a poorly defined deceleration of only 0.7 ± 1.3 units. The fragmentation time was found to be 1995 September 14 $\pm$ 16, deviating by only $\sim 0.5\sigma$ from the time of the major outburst. An assumption of no deceleration led to an equally good solution.

It appears rather unlikely that fragment B was detected after 1996. It unquestionably was observed as subset I and it may have contaminated the positions in subset III, although a preferred scenario is that this latter subset refers to another fragment.

5.3. Fragment E. Surprisingly, subset III could easily be linked with subset V, indicating that they both referred to fragment E. The five-parameter solution yielded 1995 September 11.0 $\pm$ 5.4 for the fragmentation time, deviating only 0.8σ from the onset time of the major outburst and suggesting that this fragment, too, was closely related to that event. Forcing the fragmentation time to coincide with the time of this outburst, I obtained an equally satisfactory solution, with an acceptable RMS residual of $\pm$ $0''.60$ and no systematic trends. Interestingly, an ephemeris run back to 1995 indicated that, from its birth until the end of February 1996 (thus including the entire period of subsets I and II), fragment E was always less than $2''.2$ from fragment C.

5.4. Fragment F. With the observations in subsets IV and VI as yet unaccounted for, I tried to link these two. This effort was most successful, yielding a solution with no systematic trends and with the July, September, and December 2001 positions mutually consistent. The resulting fragmentation time, 1995 October 28.3 $\pm$ 2.5, differed by 2.2σ from the onset time of the follow-up outburst. Forcing the fragmentation time to coincide with this outburst's time offered a solution that was about equally satisfactory. On the other hand, the assumption of coincidence with the major outburst led to an inferior solution with strong systematic residuals and a negative deceleration.

In the following, this fragment is called F. In August-December 1996, it should have been about $10''$ farther from C than E, and in late 1995 and early 1996 its predicted location was between B and A (in early December 1995, very close to A). Its apparent absence implies that it took a few years before this fragment became active.

An alternative scenario, with fragment F sharing its direct parent with fragment B, was not contemplated because of uncertainties in the motion of B in 2000-2001. An unlikely common origin of F and B is suggested by their diverse birth-date preferences, the major outburst being favored by B, whereas the follow-up outburst is favored by F.

5.5. Fragment A. There appears to be no indication that observations other than subset II refer to this condensation. Its deceleration relative to the other fragments was fairly high, much more than 10 units. I investigated three possible birth scenarios based on direct parents common with C, B, or E, using offsets of the observed astrometric positions of A from predicted positions of the presumed parent successively approximated by each of the three fragments. The quality of fit was always very good and nearly the same in all three scenarios. However, the fragmentation time was poorly determined and therefore nondiscriminatory. I eventually solved the problem by requiring that the separation velocity be as low as possible. This condition led to B as the most likely fragment to share a common parent with A, implying a velocity of about 1.2 m/s when its breakup just preceded the follow-up outburst. A common parent with C would have implied $\sim$ 2 m/s and a breakup at about the same time, while a common parent with E would have needed >3 m/s and a breakup soon after the separation of E from C.

TABLE 4

FRAGMENTATION MODEL SOLUTIONS FOR COMPANION NUCLEI OF COMET 73P/SCHWASSMANN-WACHMANN.

Fragmentation event's description parameter	Birth scenario for companion fragment			
	B	E	F	A
Direct parent shared with	C	C	C	B
Time of separation				
days from perihelion[a]	−16[b]	−16[b]	+41[c]	+33 ± 8[d]
date (1995 UT)	Sept. 6.9	Sept. 6.9	Nov. 2.9	Oct. 25.9
Separation velocity (m/s)				
Total	0.69 ± 0.01	1.07 ± 0.10	2.55 ± 0.08	1.19 ± 0.12
Radial	+0.52 ± 0.01	−0.91 ± 0.03	+1.74 ± 0.07	−0.27 ± 0.30
Transverse	+0.44 ± 0.01	−0.38 ± 0.25	−1.83 ± 0.09	−1.16 ± 0.10
Normal	+0.10 ± 0.01	+0.42 ± 0.06	+0.36 ± 0.03	+0.08 ± 0.01
Deceleration γ (units of 10^{-5} solar attraction)	0[e]	5.5 ± 1.2	7.48 ± 0.54	37.0 ± 2.9
Number of offset pairs used in the solution	30	27	30	42
Mean residual	±0″.20	±0″.60	±0″.71	±0″.30

[a] Minus sign = preperihelion, plus sign = postperihelion.

[b] Separation time assumed to coincide with the onset time of the major outburst.

[c] Separation time assumed to coincide with the onset time of the follow-up outburst.

[d] Determined by requiring a minimum separation velocity; error is 1σ.

[e] Deceleration assumed to be zero; when solved for, it came out to be +0.7 ± 1.3 units.

◇ ◇ ◇

[text continued from page 231]

5.6. The Proposed Fragmentation Scenario. Based on the performed calculations, I propose fragmentation solutions involving nuclei C, B, E, F, and A that are described by the optimized parameters presented in Table 4. The corresponding model for the fragmentation sequence and hierarchy of comet 73P is shown in Figure 2, which indicates that the products of the 1995 events represent two generations of fragments of the original parent nucleus, which itself was found by Boehnhardt et al. (1999) to have been less than 2.2 km across.

[text continued on page 233]

◇ ◇ ◇

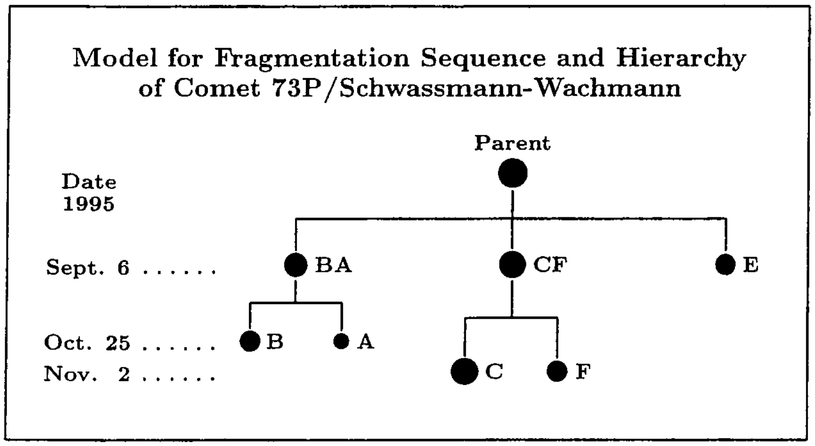


Figure 2. Proposed model for the 1995 fragmentation sequence and hierarchy of comet 73P, based on the analysis of motions of companion nuclei B, E, F, *and* A *relative to* C. *In this scheme,* BA, CF, *and* E *are the first-generation fragments of the parent nucleus, while* B, F, *and* A, *together with* C, *are the second-generation fragments. The dates of fragmentation are shown on the left.*

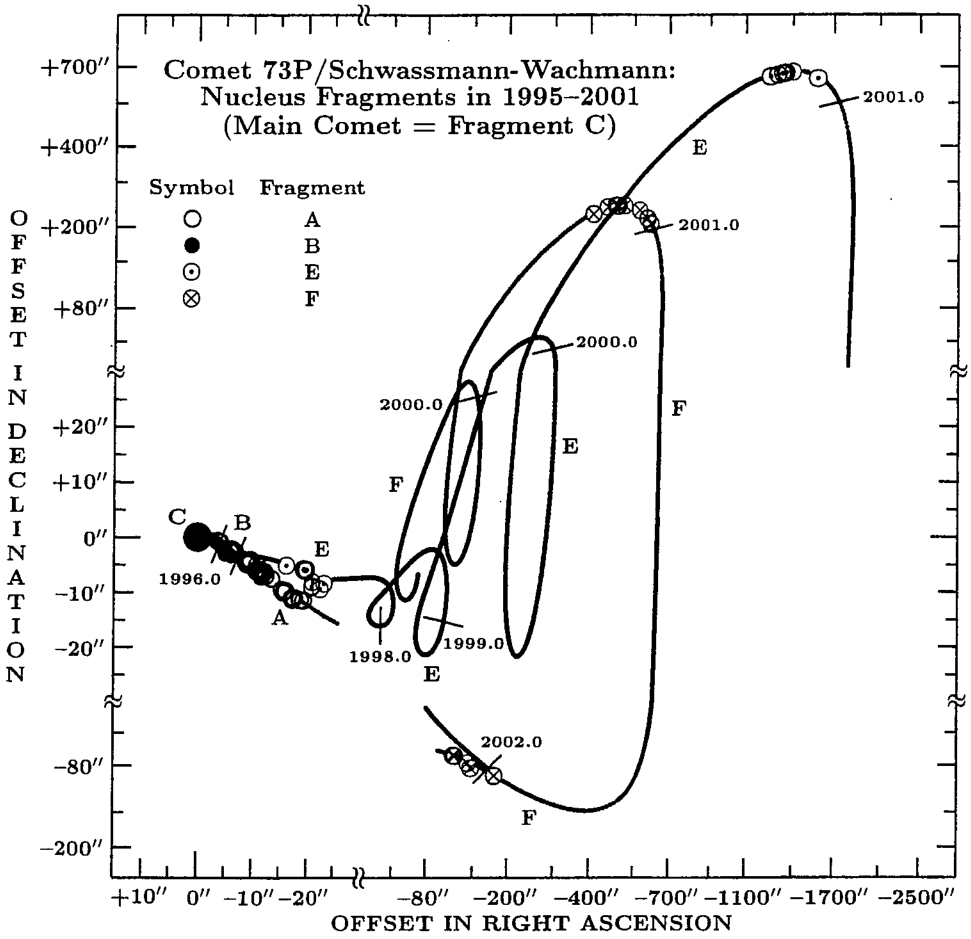


Figure 3. A fit to the observed motions of companion nuclei A, B, E, *and* F *relative to nucleus* C *between 1995 and the end of 2001. To increase clarity of the plot, the fit for fragment* F *is shown only from the beginning of 1999 on. The scale is linear within 30″ of* C, *but is proportional to an offset's cube root at larger distances.*

◇ ◇ ◇

[text continued from page 232]

Because of the strong preference of the separation times for fragments B, E, and F to coincide with the onset time of one of the two outbursts, the solutions shown in Table 4 were derived from four-parameter runs with the separation time forced accordingly. No significant error is thereby introduced, while the parameters are more robust. The results for nucleus A come also from a four-parameter run, with the fragmentation time determined by minimizing the separation velocity, which is presumably of rotational nature. Table 4 shows that this velocity is generally close to 1 m/s, with the exception of fragment F. It is possible that the first-generation fragment CF (Figure 2) was spun up during the fragmentation event of September 6-7 and that the second-generation fragment C was spun down during the event of November 2, thus regaining some inertial stability again. Calculations show that significant changes in the angular momentum of a splitting cometary nucleus can be expected (Sec. 6). Even with separation velocities as low as 1 m/s, the spin period of a nucleus 2 km in diameter comes out to be extremely short, less than 2 hours.

The observed and fitted motions of the four companion nuclei relative to nucleus C between 1995 and the end of 2001 are plotted in Figure 3 in projection onto the plane of the sky. The complex loops of the trajectories are effects of the earth's orbit about the sun. The plot shows an approximate alignment of the companions at any given time in a direction that, with time, approaches ever closer to the projected direction of the comet's orbit, a typical configuration conforming to the orbital angular-momentum law.

6. Effects of Nucleus Fragmentation on the Spin Rate

Because there still is no consensus about the mechanism that makes cometary nuclei split far from the sun and the planets, quantitative investigations of the role of rotation (one of the candidate causes) are of much interest. Here I discuss a highly idealized case of a spherical parent nucleus of diameter D_0, uniform density ρ_0, spin vector $\vec{\omega}_0$ passing through the center of mass, and moment of inertia I_0. This object is assumed to split in a mode that can be approximated

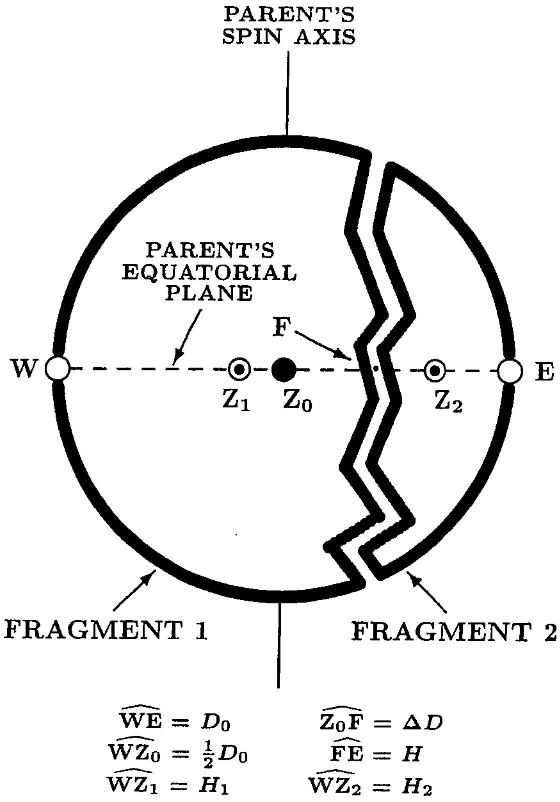


Figure 4. Splitting of a (parent) cometary nucleus (of spherical shape and uniform density and rotating about an inertially fixed spin axis) into two pieces, with a more-massive fragment 1 and a less-massive fragment 2. The mode of splitting can be approximated by slicing the nucleus along a plane parallel to its spin axis and passing through point F. Z_0, Z_1, *and* Z_2 *are, respectively, the centers of mass of the parent nucleus and the two fragments.* W *and* E *are points in the equatorial plane projected west and east.*

◊ ◊ ◊

[text continued from page 233]

by a slice along a plane parallel to the inertially fixed spin axis at a distance ΔD (Figure 4). The splitting generates two fragments shaped like spherical segments, whose dimensions along the line perpendicular to the slice in the parent's equatorial plane are $D_1 = \frac{1}{2}D_0 + \Delta D = D_0 - H$ (primary, more-massive fragment 1) and $D_2 = \frac{1}{2}D_0 - \Delta D = H$ (secondary, less massive fragment 2). Let their (unknown) initial spin vectors (both assumed to be parallel to $\vec{\omega}_0$) be $\vec{\omega}_1$ and $\vec{\omega}_2$ and their moments of inertia relative to the parent's center of mass I_1 and I_2, respectively. The conservation of momentum law and the conservation of energy law require that

$$I_0|\vec{\omega}_0| = I_1|\vec{\omega}_1| + I_2|\vec{\omega}_2|, \qquad (1)$$

$$\frac{1}{2}I_0|\vec{\omega}_0|^2(1-\lambda) = \frac{1}{2}I_1|\vec{\omega}_1|^2 + \frac{1}{2}I_2|\vec{\omega}_2|^2, \qquad (2)$$

where λ is the fraction of the rotational energy of the parent nucleus that is lost (heating, mechanical friction, etc.). Because of the symmetry, I will consider the primary fragment always on the left in Figure 4 and the secondary, whose height $H \leq D_0/2$, on the right.

The task is to find solutions for the spin rates of the fragments, $\omega_k = |\vec{\omega}_k|$ $(k = 1,2)$, that satisfy the two equations for given values of the fragmentation parameter H, the parent's spin rate, $\omega_0 = |\vec{\omega}_0|$, and the lost energy, $0.5\lambda\ I_0\ \omega^2$. The moments of inertia are known, since for the parent nucleus $I_0 = \frac{1}{60}\pi\ \rho_0\ D_0^5$, while for the fragments they are calculated from the basic equation,

$$I_k = \int_{(V_k)} r_\perp^2\ dm \qquad (k = 1,2), \qquad (3)$$

where, for either fragment, $r_\perp$ is the distance of each mass element dm of the body from its new spin axis that passes through its center of mass, while (V_k) means that the expression is integrated over the fragment's whole volume. In

Figure 4 the center of mass is shown for both the parent (Z_0) and the fragments (Z_1 and Z_2). Referring each fragment's moment of inertia to the parent's center of mass, an additional term is to be added to (3), equal to a product of the fragment's mass and the square of the distance between its center of mass and that of the parent.

The problem can readily be solved in terms of dimensionless parameters $\Omega_k = \omega_k/\omega_0$ and $J_k = I_k/I_0$ ($k = 1, 2$), as is apparent from Eqs. (1) and (2). Instead of I_0, however, I express the dimensionless moments of inertia $\Im_k$ ($k = 1, 2$) in units of $\frac{\pi}{32}\,\rho_0\,D_0^5$, in which case

$$\Im_1 = \Im + \Im_1', \tag{4}$$

$$\Im_2 = \frac{8}{15} - \Im + \Im_2', \tag{5}$$

where

$$\Im = \frac{4}{15} - \frac{1}{2}(1-\Theta)\left[1 - \frac{2}{3}(1-\Theta)^2 + \frac{1}{5}(1-\Theta)^4\right], \tag{6}$$

$$\Im_1' = \Theta^2\left(1 - \frac{1}{3}\Theta\right)(1-\Theta_1)^2, \tag{7}$$

$$\Im_2' = \left[\frac{4}{3} - \Theta^2\left(1 - \frac{1}{3}\Theta\right)\right](1-\Theta_2)^2. \tag{8}$$

Here $\Theta = 2(1-H/D_0)$ is a fragmentation parameter (Figure 4), whose range is $1 \leq \Theta < 2$; it determines the mass ratio (which is physically more important) of the fragments, $M_1/M_2 \geq 1$:

$$\frac{M_1}{M_2} = \frac{\Theta^2\,(1-\frac{1}{3}\Theta)}{\frac{4}{3} - \Theta^2\,(1-\frac{1}{3}\Theta)}. \tag{9}$$

The locations Z_1 and Z_2 of the centers of mass of the fragments are in Figure 4 described by H_1 and H_2, respectively. Defining $\Theta_k = 2H_k/D_0$ ($k = 1, 2$), one finds Θ_k from the following equations, best solved by rapidly converging iterations:

$$\Theta_1 = \Theta\sqrt{\frac{1-\frac{1}{3}\Theta}{2\,(1-\frac{1}{3}\Theta_1)}}\,, \tag{10}$$

$$\Theta_2 = \sqrt{\frac{\frac{4}{3} + \Theta^2\,(1-\frac{1}{3}\Theta)}{2\,(1-\frac{1}{3}\Theta_2)}}\,, \tag{11}$$

where $0.65 < \Theta_1 < 1$ and $1.35 < \Theta_2 < 2$. The dimensionless spin rates $\Omega_k = \omega_k/\omega_0$ are then

$$\Omega_k = \frac{8}{15}\left\{\frac{1}{\Im_1+\Im_2} \pm (-1)^{k+1}\sqrt{\left(\frac{1}{\Im_k} - \frac{1}{\Im_1+\Im_2}\right)\left[\frac{15}{8}(1-\lambda) - \frac{1}{\Im_1+\Im_2}\right]}\,\right\} \quad (k = 1,2). \tag{12}$$

Equation (12) shows that there is a constraint on the lost energy. The first term of the square-root expression is always positive as $\Im_1$ and $\Im_2$ are positive. For the second term to be positive, λ must satisfy a condition

$$\lambda < 1 - \frac{8}{15}(\Im_1+\Im_2)^{-1}. \tag{13}$$

As the mass ratio M_1/M_2 increases, the losses measured by the total rotational energy decrease, as one expects. When the energy-loss factor λ reaches its maximum value, both fragments have the same spin rate equal to $(1-\lambda)\omega_0$.

The results of this model's application are listed in Table 5 as rotation periods of the fragments, $P_k = 2\,\pi/\omega_k$ ($k = 1, 2$), for a parent's rotation period $P_0 = 6$ hours. The table shows that, as suggested in Sec. 5.6, fragments can indeed be either spun up or spun down and that especially a secondary fragment much less massive than the primary can acquire a spin rate almost twice the parent's rate. When energy losses are trivial, one fragment is spun up, the other spun down. Of course, changes in the spin rate are much greater for the smaller of the two fragments.

While these results are encouraging, one should be aware of at least two problems. One is the various assumptions on which the model rests and which imply that the results should be taken with caution. The other is the fact that, as postulated, the rotation of the fragments is extremely unstable, because the axis differs dramatically from the axis of maximum moment of inertia. One can expect that especially smaller fragments should experience violent tumbling, also aggravated — as it appears to be the case — by torques due to activity of their own.

TABLE 5
EFFECT OF NUCLEUS FRAGMENTATION ON ROTATION PERIODS OF FRAGMENTS FOR ASSUMED PARENT ROTATION PERIOD $P_0 = 6$ HOURS.

		Energy losses (percent)		Rotation periods of fragments (hr)			
				case $P_1 < P_2$		case $P_1 > P_2$	
Fragmentation parameter Θ	Fragments' mass ratio, M_1/M_2	maximum, $\lambda_{\max}$	adopted, λ	P_1	P_2	P_1	P_2
1.00	1.00	23	20	6.5	9.8	9.8	6.5
			10	5.5	13.3	13.3	5.5
			0	5.0	17.3	17.3	5.0
1.20	1.84	22	20	6.8	9.7	8.9	6.4
			10	5.8	15.0	11.3	5.2
			0	5.4	22.5	13.5	4.6
1.40	3.63	19	10	6.1	15.3	9.3	4.9
			0	5.7	30.5	10.6	4.2
1.60	9.03	13	10	6.4	11.4	7.5	4.9
			0	5.9	45.7	8.3	3.7
1.80	34.7	5	0	6.0	90.6	6.7	3.3
1.90	137	2	0	6.0	180	6.2	3.1
1.95	541	0.4	0	6.0	360	6.1	3.0

◇ ◇ ◇

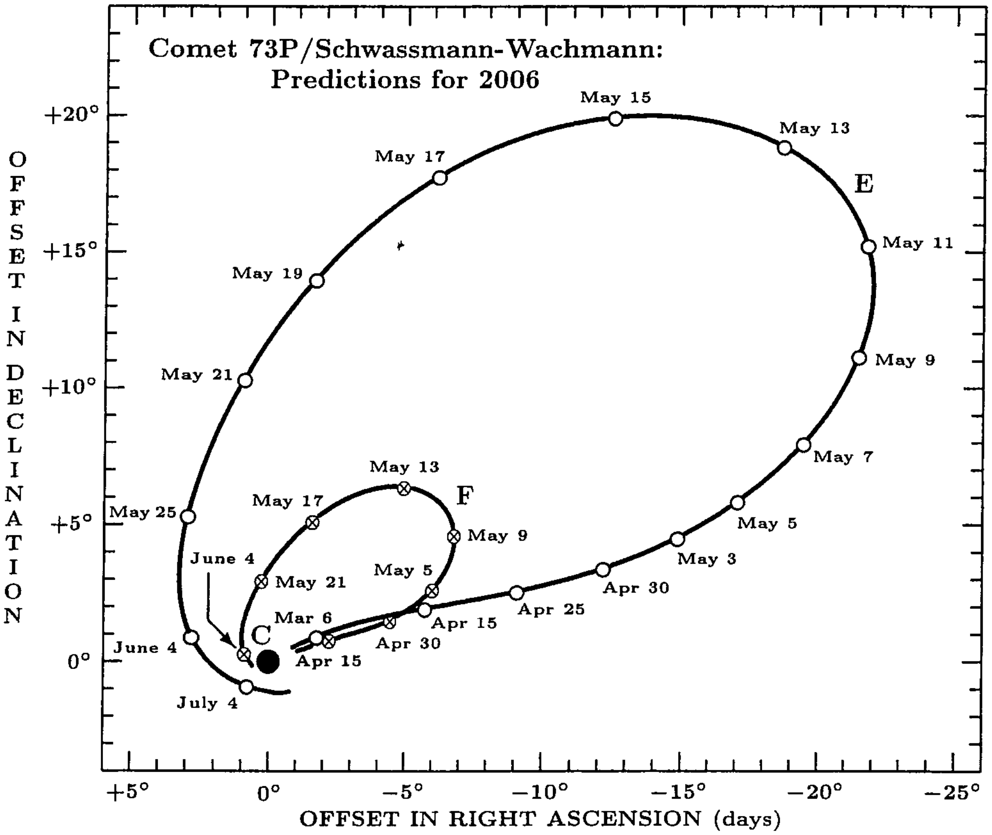


Figure 5. Predicted motion of fragments E *and* F *relative to the principal fragment* C *in projection onto the plane of the sky around the time of the close encounter of comet 73P with Earth. Unlike in Table 6, the JPL set of elements for* C *was used. The predicted distances for fragment* B *(not shown) are about 5-8 percent greater than those of* F. *The times are for* 0^{h} *TT.*

Table 6

Ephemerides for Fragments E, F, and B relative to Fragment C of Comet 73P/Schwassmann-Wachmann in 2005/2006[a].

Date (0 TT)	Distance from Earth (AU)	Astrometric offset from fragment C for					
		fragment E		fragment F		fragment B	
		separation distance	position angle	separation distance	position angle	separation distance	position angle
2005		′	°	′	°	′	°
Oct. 27	3.153	15.8	293.8	6.1	293.8	6.2	293.8
Nov. 6	2.960	17.6	294.7	6.7	294.6	6.9	294.7
16	2.761	19.7	295.4	7.5	295.4	7.7	295.4
26	2.557	22.2	296.0	8.4	296.1	8.7	296.1
Dec. 6	2.351	25.1	296.6	9.5	296.7	9.8	296.6
16	2.144	28.6	297.0	10.7	297.1	11.1	297.1
26	1.938	32.9	297.4	12.3	297.5	12.8	297.5
2006		°	°	°	°	°	°
Jan. 5	1.736	0.64	297.7	0.24	297.8	0.25	297.7
15	1.539	0.74	297.8	0.28	298.0	0.29	297.9
25	1.350	0.88	297.9	0.33	298.1	0.34	297.9
Feb. 4	1.170	1.05	297.8	0.39	298.0	0.41	297.8
14	1.002	1.28	297.6	0.47	297.8	0.49	297.6
24	0.845	1.57	297.1	0.58	297.4	0.61	297.2
Mar. 6	0.701	1.95	296.4	0.72	296.7	0.76	296.5
16	0.571	2.48	295.4	0.91	295.7	0.96	295.5
26	0.454	3.22	294.0	1.18	294.3	1.25	294.0
Apr. 5	0.349	4.30	292.1	1.59	292.3	1.68	292.1
15	0.255	6.06	289.9	2.25	290.2	2.38	289.9
25	0.170	9.48	288.9	3.55	289.1	3.76	288.8
30	0.133	12.63	290.7	4.73	290.8	5.02	290.5
May 3	0.113	15.37	293.7	5.72	293.8	6.08	293.5
5	0.101	17.63	297.1	6.49	297.3	6.90	296.9
7	0.0915	20.13	302.1	7.26	302.2	7.73	301.8
9	0.0840	22.53	308.6	7.85	308.7	8.38	308.3
11	0.0796	24.07	316.3	7.98	316.4	8.54	316.0
12	0.0788	24.20	320.5	7.78	320.6	8.34	320.2
13	0.0789	23.76	324.8	7.41	324.9	7.94	324.4
14	0.0799	22.70	329.2	6.87	329.3	7.37	328.8
15	0.0818	21.09	333.6	6.22	333.7	6.68	333.2
16	0.0845	19.09	338.3	5.52	338.3	5.93	337.7
17	0.0880	16.88	343.1	4.82	343.1	5.18	342.5
18	0.0921	14.68	348.1	4.17	348.2	4.48	347.5
19	0.0969	12.63	353.4	3.59	353.5	3.85	352.7
21	0.108	9.30	4.8	2.67	4.9	2.85	4.1
23	0.120	7.01	17.0	2.05	17.0	2.18	16.2
25	0.134	5.52	29.0	1.64	29.1	1.74	28.3
27	0.148	4.55	40.3	1.38	40.4	1.45	39.8
30	0.170	3.63	54.9	1.12	55.0	1.18	54.7
June 4	0.209	2.76	73.5	0.88	73.8	0.92	73.9

[a] Using Marsden's NEW set of orbital elements from Table 3.

◇ ◇ ◇

[text continued from page 235]

7. Predictions for the 2006 Return to Perihelion

The fragmentation sequence and hierarchy, determined by the results in Table 4 and Figure 2, allow one to provide ephemerides for the potentially surviving companion nuclei during the 2006 return of comet 73P to perihelion. Projected onto the plane of the sky, the motions of fragments E and F relative to nucleus C are plotted in Figure 5, based on the JPL orbital set from Table 3.

To avoid overcrowding of Figure 5, the ephemeris for fragment B (whose separation distances are more uncertain,

TABLE 7

EFFECT OF ORBITAL SET CHOICE ON EPHEMERIS OF FRAGMENT E RELATIVE TO FRAGMENT C NEAR CLOSEST APPROACH TO EARTH.

			Difference in astrometric offset of fragment E from fragment C					
	Orbit JPL		NEW minus JPL		NAK minus JPL		MUR minus JPL	
Date 2006 (0 TT)	separation distance	position angle	separation distance	position angle	separation distance	position angle	separation distance	position angle
Mar. 26	3°.20	293°.9	+0°.02	+0°.1	−0°.02	−0°.1	+0°.02	+0°.1
Apr. 5	4.27	291.9	+0.03	+0.2	−0.04	−0.2	+0.04	+0.2
15	5.99	289.6	+0.07	+0.3	−0.07	−0.3	+0.08	+0.4
25	9.31	288.2	+0.17	+0.7	−0.16	−0.6	+0.19	+0.8
30	12.39	289.6	+0.24	+1.1	−0.23	−1.0	+0.27	+1.2
May 3	15.11	292.4	+0.26	+1.3	−0.28	−1.3	+0.30	+1.5
5	17.39	295.6	+0.24	+1.5	−0.27	−1.5	+0.26	+1.7
7	20.02	300.4	+0.11	+1.7	−0.20	−1.6	+0.11	+1.9
9	22.71	307.0	−0.18	+1.6	+0.04	−1.6	−0.22	+1.7
11	24.78	315.1	−0.71	+1.2	+0.51	−1.3	−0.82	+1.4
12	25.24	319.6	−1.04	+0.9	+0.82	−1.1	−1.19	+1.0
13	25.12	324.1	−1.36	+0.7	+1.16	−0.8	−1.55	+0.8
14	24.33	328.7	−1.63	+0.5	+1.47	−0.5	−1.85	+0.5
15	22.90	333.4	−1.81	+0.2	+1.69	−0.3	−2.05	+0.3
16	20.93	338.2	−1.84	+0.1	+1.80	−0.2	−2.09	+0.1
17	18.65	343.1	−1.77	0.0	+1.78	0.0	−2.00	−0.1
18	16.29	348.3	−1.61	−0.2	+1.64	+0.1	−1.81	−0.2
19	14.04	353.7	−1.41	−0.3	+1.45	+0.1	−1.58	−0.3
21	10.31	5.2	−1.01	−0.4	+1.05	+0.2	−1.14	−0.4
23	7.72	17.3	−0.71	−0.3	+0.74	+0.3	−0.80	−0.4
25	6.04	29.3	−0.52	−0.3	+0.53	+0.3	−0.59	−0.3
27	4.94	40.5	−0.39	−0.2	+0.40	+0.2	−0.44	−0.2
30	3.91	54.9	−0.28	0.0	+0.29	+0.1	−0.31	0.0
June 4	2.94	73.4	−0.18	+0.1	+0.18	−0.2	−0.20	+0.2

◇ ◇ ◇

[text continued from page 237]

but expected to be 5-8 percent greater than those of fragment F) is not plotted. In tabular form, the ephemerides for all three fragments, calculated with the 1995-2005 set of elements for nucleus C (orbit 'NEW' in Table 3), are presented in Table 6. Ephemerides for fragments E and F starting in late September 2005 were published electronically (Sekanina 2005). No ephemeris is provided for fragment A, whose high deceleration strongly suggests that it has not survived.

An important issue is that of the accuracy of the ephemerides. Their intrinsic accuracy is determined by the fragmentation sequence and hierarchy of the comet. If the companion fragments were correctly identified, the uncertainties in their 2006 positions should be fairly small, perhaps on the order of 10′ or so. The uncertainty in the ephemeris for B is greater than this, because this fragment has not apparently been observed since 1996. The available 2.5-month arc is therefore extrapolated over a period of time about 50 times as long. In addition, its survival is statistically less likely than that of fragments E and F.

Apart from its intrinsic accuracy, an ephemeris for any companion fragment depends critically on the set of orbital elements used, as both the apparent separation distance and the position angle of companion fragments are very sensitive to the perihelion time. With the comet recovered, this has become only a minor issue. To illustrate it, I show in Table 7 the scatter among the four orbits from Table 3 in the separation distance and position angle of fragment E relative to the principal fragment in the period of time from 2006 March 26 to June 4. As the perihelion time will further be refined, one can conclude from Table 7 that the maximum effect on the separation distance of fragment E on May 16 is about 0′.5 for a change of 0.001 day in the perihelion time.

8. Conclusions

The collected astrometric data for comet 73P were found to refer mostly to primary fragment C or one of four companion fragments: subset I referring to component B, subset II to A, subsets III and V to E, and subsets IV and VI to F. Only a few data points referred to the other, fleeting fragments, which are ignored in this paper.

There is a strong correlation between the comet's fragmentation sequence and hierarchy, on the one hand, and its two outbursts in 1995 on the other hand. The first, major outburst, beginning around September 6 (more than two weeks before perihelion) had an amplitude of 5 magnitudes and a rise time of 5 weeks, and it accompanied the breakup of the parent nucleus into fragment E and two precursors to fragments A + B and C + F. The follow-up outburst, on November 2 or so (some 6 weeks after perihelion), had an amplitude of nearly 1.5 magnitudes and a rise time of two weeks; it accompanied the splitting of one of the precursors into fragments C and F. This evidence strongly supports a hypothesis proposed for the split comet C/2001 A2 (Sekanina *et al.* 2002), which says that the presence or absence of an outburst related to a fragmentation event depends on the steepness of the size distribution of the accompanying cloud of particulate debris.

The decelerations of fragments B, E, and F suggest that these are sizable bodies like fragments of other comets known to have survived for one or more revolutions about the sun (*e.g.*, Sekanina 1999). On the other hand, fragment A was much smaller and is not expected to have survived. Given the dimensions of the parent nucleus (Boehnhardt *et al.* 1999), and assuming rotational nature of the separation velocities, their derived range (mostly near 1 m/s, but 2.5 m/s for fragment F) suggest a rapid rotation with major fragmentation-driven spin-up and/or spin-down effects.

The problem of identifying the companion fragments can never be dismissed as one of no concern. Especially the similarities between nuclei B and F are most intriguing. The strongest argument against the identity of (or a very close relationship between) the two is based on fitting the astrometric observations in the second half of 2001. All investigated scenarios pointed to major discrepancies when these data were assumed to refer to fragment B, its birth coinciding essentially with the onset of the major outburst of 1995. The difficulties disappeared instantly, once the 2000 and 2001 observations were assigned to another fragment, F, with its origin linked to the follow-up outburst. Although one can argue that the inverse-square power law adopted for the variations in the nongravitational deceleration may not always approximate the observed motions of comet fragments satisfactorily enough, it is easy to counter by pointing out that the fitting obstacles involving observations at large heliocentric distances and spanning a period as short as a few months cannot be of this origin because any minor acceleration effect (such as these forces appear to be) is much too gentle to make so much difference so suddenly.

A prediction of the motions of companion fragments during the comet's close approach to Earth in mid-May 2006 shows that the separation distance from C should peak at more than 24° for fragment E, but near 8° to $8\overset{\circ}{.}5$ for B and F. The uncertainties of the prediction are difficult to estimate, confined perhaps to $10'$ along the orbit, but they are negligibly small across the orbit. Since the rate of fragment disintegration is unknown, one of three possible recovery states can be expected at each predicted location: (i) no apparent decay since the previous observations, in which case the result should be a relatively easy detection of the fragment; (ii) some moderate crumbling, in which case there should be a number of fainter fragments distributed along the orbit at distances from C about equal to or somewhat greater than the predicted location; or (iii) advanced or complete disintegration, in which case there is a little or no chance of detecting any fragments at the location.

As a final remark, one should not ignore the remote possibility of unknown fragments released at any time after the 1995 perihelion (including far from the sun). For example, a fragment separating from C sixteen days before the 2001 perihelion with the same separation velocity and subjected to the same deceleration as fragment E would on 2006 May 11.0 TT be located $11\overset{\circ}{.}3$ from C at position angle $316\overset{\circ}{.}8$ — farther than some of the 1995 fragments!

In the short run, the presented results should benefit all observers who plan to participate in monitoring the comet's nuclei during its upcoming return to perihelion, whether optically, by radar, in the infrared, etc., especially during the close encounter with Earth in mid-May 2006. The major companion nuclei are thus ready for searches in a coordinated effort to observe fragments down to the least dimension that can possibly be detected.

More generally, this is a contribution in the quest to understand cascading fragmentation of comets by presenting a sequence and hierarchy of one of the most difficult multiply split comets. This work thus provides fundamental information on the disintegration processes in comets and on their physical evolution and demise, with broad applications to cometary science, including the exploration of comets by space missions.

Acknowledgements. I thank M. S. W. Keesey and B. G. Marsden for information on their orbit determination efforts and H. Boehnhardt for reading an earlier draft of this paper and commenting on it. This research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration and funded through the internal Research and Technology Development program.

REFERENCES

Beyer, M. (1931). "Komet 1930d (Schwassmann-Wachmann)", *Sterne* **11**, 17-18.

Boehnhardt, H.; and H. U. Käufl (1995). "Comet 73P/Schwassmann-Wachmann 3", *IAU Circ.* 6274.

Boehnhardt, H.; H. U. Käufl; P. Goudfrooij; J. Storm; J. Manfroid; and K. Reinsch (1996). "The Break-Up of Periodic Comet Schwassmann-Wachmann 3: Image Documents from La Silla Telescopes", *ESO Messenger* No. 84, 26-29.

Boehnhardt, H.; N. Rainer; K. Birkle; and G. Schwehm (1999). "The Nuclei of Comets 26P/Grigg-Skjellerup and 73P/Schwassmann-Wachmann 3", *Astron. Astrophys.* **341**, 912-917.

Boehnhardt, H.; S. Holdstock; O. Hainaut; G. P. Tozzi; S. Benetti; and J. Licandro (2002). "73P/Schwassmann-Wachmann 3 — One Orbit After Break-Up: Search for Fragments", *Earth Moon Planets* **90**, 131-139.

Candy, M. P. (1979). "Comet 1979g", *IAU Circ.* No. 3393.

Crovisier, J.; N. Biver; D. Bockelée-Morvan; P. Colom; E. Gérard; L. Jorda; and H. Rauer (1995). "Comet 73P/Schwassmann-Wachmann 3", *IAU Circ.* 6227.

Crovisier, J; D. Bockelée-Morvan; E. Gérard; H. Rauer; N. Biver; P. Colom; and L. Jorda (1996). "What Happened to Comet 73P/Schwassmann-Wachmann 3?", *Astron. Astrophys.* **310**, L17-L20.

Dartayet, M. (1931). "Beobachtungen der Kometen 1930d (Schwassmann-Wachmann) und 1930e (Forbes)", *Astron. Nachr.* **241**, 277-278.
Green, D. W. E., ed. (1996a). "Comet 73P/Schwassmann-Wachmann 3", *IAU Circ.* 6234.
Green, D. W. E., ed. (1996b). "Comet 73P/Schwassmann-Wachmann 3", *IAU Circ.* 6246.
Green, D. W. E., ed. (1997). "Comet 73P/Schwassmann-Wachmann 3", *Internat. Comet Quart.* **19**, 47.
Green, D. W. E., ed. (2000a). "Comet 73P/Schwassmann-Wachmann 3", *Internat. Comet Quart.* **22**, 58, 100, 145.
Green, D. W. E., ed. (2000b). "Comet 73P/Schwassmann-Wachmann 3", *IAU Circ.* 7534.
Green, D. W. E., ed. (2001). "Comet 73P/Schwassmann-Wachmann", *Internat. Comet Quart.* **23**, 166.
Green, D. W. E., ed. (2005). "Comet 73P/Schwassmann-Wachmann", *IAU Circ.* 8623.
Hartmann, J. (1931). "Photographische Positionen des Kometen 1930d (Schwassmann-Wachmann)", *Astron. Nachr.* **241**, 275-278.
Marsden, B. G. (1984). "Comets in 1979", *Quart. J. Roy. Astron. Soc.* **26**, 106-114.
Marsden, B. G., ed. (1996). "Observations of Comets: 73P/Schwassmann-Wachmann 3", *Minor Planet Circ.* 26211, 26444-26445, 26610-26611.
Marsden, B. G., ed. (2000). "Observations of Comets: 73P/Schwassmann-Wachmann 3", *Minor Planet Circ.* 41633.
Marsden, B. G., ed. (2001). "Observations of Comets: 73P/Schwassmann-Wachmann 3", *Minor Planet Circ.* 41824-41825.
Nakano, S. (2000). "Orbital Elements: 73P/Schwassmann-Wachmann 3 [components C and E]", *Minor Planet Circ.* 41717.
Nakano, S.; and Green, D. W. E., eds. (2004). *2005 Comet Handbook*, *ICQ* **26**(4a), H9.
Nakano, S.; and B. G. Marsden, ed. (2003a). "Orbital Elements: 73P/Schwassmann-Wachmann 3-C", *Minor Planet Circ.* 48382.
Nakano, S.; and B. G. Marsden, ed. (2003b). "Orbital Elements: 73P/Schwassmann-Wachmann 3-E", *Minor Planet Circ.* 48383.
Öpik, E. J. (1963). "Photometry, Dimensions, and Ablation Rates of Comets", *Irish Astron. J.* **6**, 93-112.
Sekanina, Z. (1978). "Relative Motions of Fragments of the Split Comets. II. Separation Velocities and Differential Decelerations for Extensively Observed Comets", *Icarus* **33**, 173-185.
Sekanina, Z. (1982). "The Problem of Split Comets in Review", in *Comets*, ed. by L. L. Wilkening (Tucson: Univ. of Arizona Press), 251-287.
Sekanina, Z. (1989). "Nuclei of Two Earth-Grazing Comets of Fan-Shaped Appearance", *Astron. J.* **98**, 2322-2345 and 2377-2382.
Sekanina, Z. (1999). "Multiple Fragmentation of Comet Machholz 2 (P/1994 P1)", *Astron. Astrophys.* **342**, 285-299.
Sekanina, Z. (2005). "Comet 73P/Schwassmann-Wachmann", *Central Bureau Elec. Telegram* No. 237.
Sekanina, Z.; H. Boehnhardt; H. U. Käufl; and K. Birkle (1996). "Relationship Between Outbursts and Nuclear Splitting of Comet 73P/Schwassmann-Wachmann 3", *JPL Cometary Science Team Preprint* No. 163.
Sekanina, Z.; P. W. Chodas; and D. K. Yeomans (1998). "Secondary Fragmentation of Comet Shoemaker-Levy 9 and the Ramifications for the Progenitor's Breakup in July 1992", *Planet. Space Sci.* **46**, 21-45.
Sekanina, Z.; E. Jehin; H. Boehnhardt; X. Bonfils; O. Schuetz; and D. Thomas (2002). "Recurring Outbursts and Nuclear Fragmentation of Comet C/2001 A2 (LINEAR)", *Astrophys. J.* **572**, 679-684.
Van Biesbroeck, G. (1930). "Observations of Comets at the Yerkes Observatory", *Astron. J.* **41**, 1-4.

Φ Φ Φ

The CARA Project and the Af(rho) Approach to Cometary Photometry*

Giannantonio Milani
Italian Comet Section

Abstract. *The project named "Cometary Archive for Amateur Astronomers (CARA) was developed among a group of Italian comet observers and is devoted to CCD photometry of cometary comae for the derivation of the aperture-independent quantity $Af\rho$. The main goal is to create a photometric numerical archive. In its current status, the project concerns mainly the dust component of cometary emission, but the possibility of getting data also for the gas component (with proper techniques) is under consideration. Filtered observations are highly encouraged (especially in the R and*

---

* Written as a detailed version of a talk presented at the IWCA III, Meudon, France, 2004 June 4–6. Editor's note: contributed papers from IWCA III have been published over several *ICQ* issues in 2005, with additional ones planned for 2006.

Cousins I bands, as well with a 647-nm narrowband filter close to the Vilnius S band), and specific basic observing procedures are defined. In order to yield the highest possible homogeneity in the database, a first release of the dedicated software for Afρ calculation is available (for Windows and Linux platforms). The data and the software can be freely downloaded from the CARA website. Some early plots of recent comets are presented as an example of what we are working for.

Introduction

The CARA (Cometary Archive for Amateur Astronomers) is a project developed in recent years among a group of active Italian CCD observers. At first, the main goal was to check the possibilities offered by the new digital techniques now available to amateurs, as it was clear that more scientific information could be extracted from amateur CCD images than from visual and photographic techniques. To amateur astronomers, one of the more fascinating possibilities of the new digital techniques concern morphological coma analysis, but this can be performed in bright comets only, where a high signal-to-noise ratio can be achieved (and, at any rate, the interpretation of processed images usually is not obvious). So, looking for a more general way of observing comets, particular attention was paid to the photometry that can be performed on nearly all observable comets. The starting point was the photometric experience of Herman Mikuž (see Mikuž and Dintiniana 1994) and the basic guidelines contained in the *ICQ Guide to Observing Comets* (Green 1997).

The first trials were performed with unfiltered images, but in order to improve our observing technique, we soon considered the move toward observations using wide-band filters (in particular, *R* and Cousins *I* photometric bands; Bessel 1990). We soon adopted a procedure of employing standard photometric windows defined in spatial size (in km) at the comet instead of measuring the classical total magnitude (Milani 2003a). In this way, we are able theoretically to have quantitative information concerning the same part of the inner coma from night to night — this inner coma being characterized by nearly the same physical phenomenology (*e.g.*, jets, halos, *etc.*) — and to monitor a comet's behavior during its apparition. The main reference window is set at a radius of 50000 km, and other windows are usually sub-multiples of the main one (*e.g.*, 25000 or 12500 km). Smaller windows can be eventually added if the image scale is large enough. Bigger ones are usually not useful, but their use cannot be excluded at all in some circumstances. The use of this method clearly differentiates CCD techniques from visual observations, considering it as a stand alone and complementary technique.

An important task was to find an ideal compromise between scientific results and an affordable observing and reduction technique using a methodology within the reach of amateur astronomers. Techniques that are too time-consuming and complex appear to be unproductive in the non-professional arena; on the other hand, an overly simplistic approach does not yield data of good-enough quality for scientific use. A very natural step, and a fairly good compromise, was to use the *Afρ* quantity of A'Hearn *et al.* (1984), which has just the characteristics that we were looking for (see Fulle 2000).[1] A collaboration with some professional astronomers allowed us to better define our goals. Being the first in the non-professional arena to gather *Afρ* data, we also had to consider a proper way for collecting and storing data. In 2001, our basic experience was judged good enough to move toward the defining of a basic program that was realized during the following year. Thus, a website and an on-line archive was built for this purpose at URL `http://cara.uai.it`. At the website, one can find more information about the program itself and the recommended observing techniques.

The CARA, in the current phase of development, is intended as a numerical database of photometric data concerning comets, based on a specific coordinated program. The name "Cometary Archive for Amateur Astronomers" was suggested by Gyula Szabó (Physics Department and Observatory of Szeged, Hungary), who also introduced the project to the MACE Congress 2003; just after that meeting, the official website was created. The CARA was created with the support of the Italian Union of Amateur Astronomers. CARA is, and probably always will be, a developing project, the development overseen by a working group but open to everyone interested.

Why Use the *Afρ* Quantity?

The *Afρ* quantity was introduced by A'Hearn *et al.* (1984) with the aim of comparing photometric data obtained with different instruments and geometric circumstances. At that time, this quantity proved useful for observations performed with photoelectric photometers, but nowadays it is commonly derived also from the analysis of CCD images. There are several advantage in using this quantity, chiefly:

- It is simple and affordable for amateur astronomers.
- The *Afρ* quantity refers to the "stationary coma" model, where is assumed that dust expands at constant speed, and, if this condition is satisfied, it is independent of the measuring window used for photometry. This greatly reduces instrumental errors, as it is much less sensitive to the size of the photometric window.
- It allows amateur astronomers to obtain sets of data that are comparable with those obtained with professional equipment.

---

[1] The parameter introduced by A'Hearn and colleagues in the 1980s that is intended to be independent of the size of the aperture through which the dust is observed. Their quantity $Af\rho$ is given by $A(\theta)f\rho = qr^2\Delta F_\lambda/d$, where A is the Bond albedo for the particular scattering angle (θ); f is the so-called "filling factor" of the grains in the field-of-view, ρ is the radius of the assumed-circular field-of-view; Δ and r are given in AU; the mean cometary continuum flux averaged over the filter bandpass (F_λ) is given in erg cm^{-2} s^{-1} Å^{-1}; d is the diameter of the field-of-view in arcsec; and q is a coefficient that is a function of solar flux (tabulated by A'Hearn *et al.* 1995, *Icarus* **118**, 223). The filling factor is the number of grains per unit area, divided by the area of the field-of-view, times their mean cross-section. As a crude estimate, the value of $Af\rho$ in 1000 cm roughly equals the production of dust in metric tons per second. There are many assumptions used in this quantity, however, assuming a static picture for size distribution and physical nature of the scattering particles and for expansion velocity (thus somewhat analogous to the situation with the Haser model). – Ed.

To produce data that are useful for the CARA project, some basic instrumental requirements are needed:

- A CCD camera with linear response.
- Filtered data are highly encouraged with Cousins R and I, Gunn R, and 647-nm narrowband (close to Vilnius S; see Fulle 1997) filters.
- Unfiltered data can be used for dusty comets that are not too close to the sun, especially if no other data are available, but this is not suggested as a general rule; U, B, and V filters are not considered because of the strong gas contamination, except in rare specific cases.
- Any telescope can be used, but reflectors are preferred because they are not affected by chromatic aberration.
- Images must be properly processed (dark-frame-subtracted and flat-field-corrected) and have a suitable signal-to-noise ratio.

The first trials for $Af\rho$ measurements were done with a simple BASIC computer-programming code, which was later improved by Gyula Szabó and converted to C-language code; eventually a more-user-friendly software was developed by Roberto Trabatti with further improvements. At present, two releases are available for Windows and Linux operating-system (OS) platforms, and can be freely downloaded from the CARA web site (`http://cara.uai.it`). Recently, particular attention was paid to improving the Windows version (named `Winafrho`), as the Microsoft Windows-OS platform is the more common among amateur astronomers. Also, most commercial CCD cameras are provided by manufacturers with their controlling software running under Windows. The last `Winafrho` release was recently updated with a tool for performing aperture-photometry measurements from FITS format files; so, except for the pre-processing of the images (dark subtraction, flat-field correction), `Winafrho` is already stand-alone software. Some trials with highly asymmetric comets showed that — at this stage — systematic discrepancies (within 5% accurancy) introduced by the use of a square window (instead of a circular window) are well below our average errors: on average close to 10-20 percent.

A relevant improvement concerns also a standard method for determining the sky-background value; in this way, personal choices are reduced to a minimum level, granting a much higher homogeneity in the database. $Af\rho$ is a highly sensitive quantity, and small differences in background do not cause negligible discrepancies. Furthermore, the data of the reference stars can be selected now in a few seconds from the on-line Hipparcos/Tycho professional databases, providing the best possible source for star magnitudes. An important advantage to this is that an output file with the measured $Af\rho$ value, written in the CARA archive format, is generated as `afrho.dat`. Existing files can be easily updated with new measurements. The Windows software at present allows one to calculate the $Af\rho$ quantity (in cm) for a given comet through a square measuring window, granting a much better automation of the measurement (when compared to the previous releases). The estimated errors do not yet take into account all noise sources, and it appears that — in some situations — the software produces an overly optimistic value, so that in this stage it must be considered as merely indicative). In most cases, the expected accurancy is close to 10-20 percent. Specific guidelines written by Roberto Trabatti on how to use the software can be downloaded from the CARA website.

◇ ◇ ◇

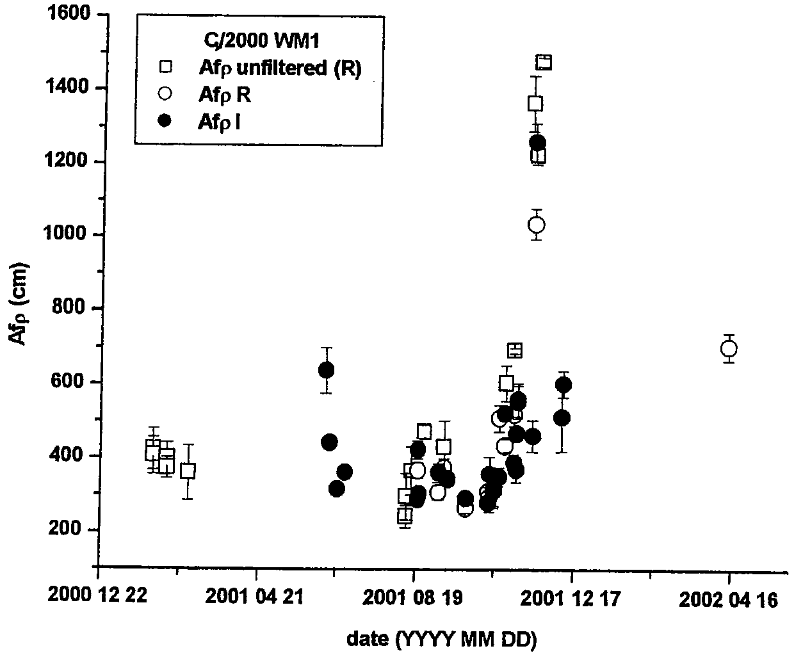


Figure 1. Comet C/2000 WM$_1$ *was used for a complete test of observing and reduction techniques. An outburst was observed in mid-November 2001. Here the parameter* $Af\rho$ *is plotted as a function of date, with different symbols indicating photometry that is unfiltered (open squares) or obtained with R (open circle) or I (filled circles) filters.*

The CARA Archive Format

The CARA archive was designed for a limited amount of data written in a format useful for immediate analysis; it has a simple basic structure similar to that of the Lowell Cometary Database. As noted above, one of our main tasks in creating the archive was first to define the observing method, filters, and nearly all relevant observing and reduction techniques. In this way, the number of data to be entered into the archive is smaller, and the archive itself is easier to read and use.

The data entered in the archive format are: comet designation (in packed Minor Planet Center form), date (given as digitally as year, month, date to 0.01 day in UT with no spaces), geocentric and heliocentric distances (in AU), phase angle (in degrees), photometric band, the observed magnitude, measuring-window radius (in km), *Afρ* (in cm) and error, reference-star source, observer code (a parenthetical number after the 3-letter code indicating that a specific instrument was used, allowing for the specification of more than one instrument), URL where one can find images (if any), and remarks (for instance, the catalogued number of the reference star). Some improvements (but not basic changes) are under development also for the archive format.

An example of the archive format is provided below. The URL (columns 82-110) and remarks (111-161) columns are omitted from this example due to space constraints on the printed page. The remarks omitted here include such items as specification of use of a 647-nm filter, a comment about thin cirrus or passing clouds being present, and specific star designations.

```
Comet     YYYYmmDD.dd Delta   r   Phase B  Magn. Radius  Afrho   Error Ref Obs.

CK01Q040  20040513.85 0.393 0.963 85.47 I  5.658 012438 0006167 00069 HIP LIG(2)
CK01Q040  20040513.85 0.393 0.963 85.47 I  6.454 006031 0006106 00068 HIP LIG(2)
CK01Q040  20040513.85 0.393 0.963 85.47 S  5.791 024876 0003073 00037 HIP LIG(2)
CK01Q040  20040513.85 0.393 0.963 85.47 S  6.630 012438 0002839 00034 HIP LIG(2)
CK01Q040  20040513.85 0.393 0.963 85.47 S  7.434 006031 0002793 00035 HIP LIG(2)
CK01Q040  20040513.88 0.394 0.963 85.46 S  5.444 026596 0004123 00226 GSC SOS
CK01Q040  20040513.88 0.394 0.963 85.46 S  6.103 012839 0004632 00256 GSC SOS
CK01Q040  20040513.88 0.394 0.963 85.46 S  7.030 006420 0004203 00223 GSC SOS
CK01Q040  20040513.88 0.394 0.963 85.46 S  7.542 003668 0004310 00249 GSC SOS
CK01Q040  20040513.88 0.394 0.963 85.46 S  4.722 048323 0004248 00028 HIP MIL
CK01Q040  20040513.88 0.394 0.963 85.46 S  5.526 023752 0004120 00028 HIP MIL
CK01Q040  20040514.83 0.412 0.962 84.69 R  5.014 048335 0004263 00028 HIP TIR
CK01Q040  20040514.83 0.412 0.962 84.69 R  5.647 025318 0004545 00031 HIP TIR
CK01Q040  20040514.83 0.412 0.962 84.69 R  6.682 011508 0003855 00028 HIP TIR
CK01Q040  20040514.86 0.412 0.962 84.66 S  6.210 012417 0004604 00188 HIP TIR
CK01Q040  20040514.86 0.412 0.962 84.66 S  6.973 006209 0004558 00187 HIP TIR
CK01Q040  20040514.86 0.412 0.962 84.66 S  8.205 003104 0002931 00121 HIP TIR
CK01Q040  20040515.87 0.433 0.962 83.76 I  4.354 038875 0007944 00080 SAO TRB(1)
CK01Q040  20040515.87 0.433 0.962 83.76 I  4.953 024880 0007148 00072 SAO TRB(1)
CK01Q040  20040515.87 0.433 0.962 83.76 I  5.869 012440 0006151 00062 SAO TRB(1)
CK01Q040  20040515.87 0.433 0.962 83.76 I  6.844 006220 0005012 00051 SAO TRB(1)
CK01Q040  20040518.88 0.502 0.963 80.72 S  6.200 026885 0003182 00162 HIP SOS
CK01Q040  20040518.88 0.502 0.963 80.72 S  6.786 014027 0003554 00183 HIP SOS
CK01Q040  20040518.88 0.502 0.963 80.72 S  7.596 007013 0003371 00178 HIP SOS
```

As a basic procedure, we suggest the use (when possible) of three standard photometric windows, defined in km at the comet. This helps to check how much the *Afρ* quantity is independent of the measuring window and provides a fast preliminary comparison among the data. From a theoretical point of view, if we consider a so-called "stationary-coma model", where dust is ejected isotropically at a constant speed from a spherical nucleus, we expect that the *Afρ* measurement is independent of the size of the measuring window. So, checking how constant the *Afρ* measurements are for different windows allows one also to check how close we are to the stationary model. At any rate, we must be aware that this cometary model is a very simplified approach. In a number of cases, it apparently works fine, but the data interpretation is not obvious.

For a number of active comets it is found that *Afρ* is nearly constant between ≈ 5000 and 50000 km or so, but many comets show some kind of dependence upon the size of the measuring window. One of the reasons why a stationary model does not match the real coma is because radiation pressure accelerates dust grains tailward. This effect is crearly seen in *Afρ* values referred to very large measuring windows, where the divergence from a radial expansion at constant speed is much higher. But radiation pressure is always present on dust, even at a small distance from the nucleus. Using very small measuring-window sizes, we usually find that *Afρ* appears lower than in the outer regions; this is because we are measuring at resolutions too close to the seeing limit (or below it) and our data are undersampled. For this reason, a window size at least 3-4 times larger that the seeing FWHM (full-width at half-maximum intensity) is recommended.

One of the main problems concerns the choice of reference stars, as at present there is a lack of a large source for *R* and *I* magnitudes. Landolt sequences unfortunately can be seldom used because, in most cases, amateur astronomers do not have photometric nights at their observing sites, and the ideal solution is to have at least a good reference star in the frame or, alternatively, one that is not too far from the comet (possibly within 1°). To have a Landolt star very close to the comet is a rare event. At present, we extrapolate *R* and *I* magnitudes by means of a polynomial, selecting stars close to the solar color ($0.4 < B{-}V < 0.8$; Milani 2003b, Caldwell *et al.* 1993). Using stars with a color index close to that of the sun (close to the color of reflected sunlight) minimizes photometric errors due to the different colors of the reference and measured objects. So, at our level of accuracy, it is not necessary to perform a complex photometric calibration.

The use of main-sequence stars is recommended, but — in the suggested $B-V$ range — the discrepancy among dwarf- and giant-star branches is fortunately negligible (usually within 0.01-0.02 mag), so in most cases also stars of unknown spectral branch (but with good enough specified photometric accuracy — at least < 0.1 magnitude, but much better if < 0.05 or so) can provide a reliable result. The use of the narrowband filter centered at 647 nm (10-nm FWHM) is now a common CARA standard for bright comets (the strong light absorption does not allow one to use it on faint objects). This filter is centered in a spectral region where gas emissions are negligible and provide much-more-accurate $Af\rho$ quantities. In some bright comets, where there is provided useful information about the gas contamination of R- and I-band data, contamination can be as high as 40-60 percent in some cases. Other cases showed that the differences among wide and narrowband filters are negligble, underscoring how comets are different from each other and showing that using average solutions can lead to wrong results. As cited before, a good way for providing magnitudes for this 647-nm filter was to approximate it to the S band of the Vilnius photometric system. A specific polynomial (Milani 2004, unpublished; source data extracted from Montgomery *et al.* 1993 and from Boyle *et al.* 1998) is used to extrapolate S magnitudes starting from V magnitudes and $B-V$ color indexes.

At present, the Hipparcos-satellite catalogue is suggested as the main source, as in most cases the average accuracy is close or better than 0.05 magnitude, and for a number of stars there is already provided an I (Cousins) magnitude. The Tycho version of the Hipparcos catalogue is suggested as a second source (selecting stars with an claimed accuracy better than 0.1 magnitude). These catalogues on an average allow one to find at least one useful reference star close enough to the comet for convenience. We are working also to get better R- and I-magnitude values and to extend the sources for reference stars to other catalogues as new references become available.

Early Results on Recent Comets

Some results on recent comets are presented as an example of what can be extracted from our observations from a first analysis. Early data were obtained with unfiltered observations, as well as with R and I filters. More recently, the S-band (close to the 647-nm narrowband) filter was added.

C/2000 WM$_1$

This comet was actively monitored by Italian observers between 2001 and 2002, and it was for us a good test for $Af\rho$ calculations and observing techniques. During the apparition, we detected an outburst of the comet between 2001 Nov. 15 and 20. The $Af\rho$ data appeared in fairly good agreement with professional ones published for the same comet (see Figure 1).

◇ ◇ ◇

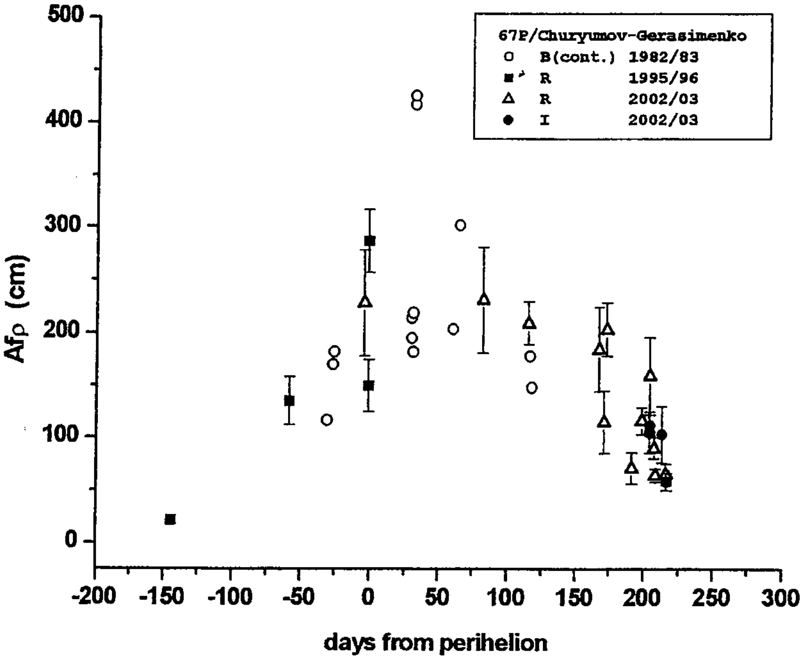


Figure 2. Comet 67P/Churyumov-Gerasimenko shows a recurrent behavior with a peak of the Afρ quantity value around 50 days after perihelion. The graph also includes plotted data from the Lowell Cometary Database for the 1982-1983 apparition; data for the 1995-1996 and 2002-2003 apparitions are by observers who have joined the CARA project.

67P/Churyumov-Gerasimenko

Comet 67P was a fortunate case of positive collaboration between professional and amateur astronomers — as the *Afρ* measurements, tail measurements, photometry, and imaging performed by CARA observers provided useful information for Rosetta-spacecraft scientists. An alert came directly from Marco Fulle (one of the Rosetta Team scientists) during an organizing CARA meeting held at the Rijeka Observatory (Croatia) in early 2003, just after the new Rosetta target comet was selected. A collaboration among observers and some professional astronomers allowed us to run immediately an observing campaign on 67P and also to collect and measure data from the previous apparition (see Figure 2). As a result, CARA data appear in some talks presented at the Rosetta workshops and procedings and in other papers concerning this comet (Weiler *et al.* 2004; Fulle *et al.* 2004). We also attended the European Space Agency Workshop held in Capri in October 2003. Further data have been recently analyzed for this comet and will be available soon.

◇ ◇ ◇

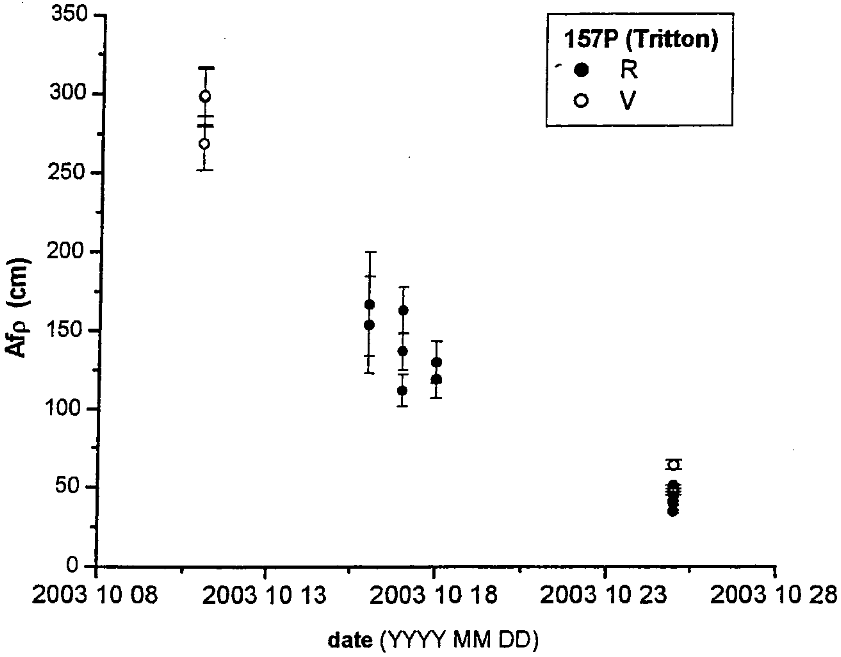


Figure 3. The fast fading of comet 157P/Tritton is well shown by the Afρ quantity plotted here. In this case, V-band data were also included, as we assumed that the comet was in a nearly inactive phase, with little gas production.

◇ ◇ ◇

157P/Tritton

The fading of comet 157P/Tritton was well monitored by *Afρ* measurements. In this case, some *V*-band observations were used, as C_2 contamination was assumed to be poor in the final phase of the fading. The trend of the *Afρ* quantity is nearly constant, showing that cometary activity was dramatically dropping. Probably in this phase the nucleus became nearly inactive (see Figure 3).

C/2002 T7

C/2002 T7 provided quite interesting results, showing a peculiar behavior in its light curve with an apparent outburst on November-December 2003. A more accurate analysis immediately revealed that the observed brightening is in fairly good agreement with what is expected from a phase effect, due to the small phase angle of that period. The phase-angle effect is due to the dust component only and can cause a possible brightening for phase angles smaller than $\approx 30°$. Our analysis just shows that, in this critical range of phase angle, the brightening of C/2002 T7 was 0.036 magnitudes/degree, in fairly good agreement with what was found for comets C/1980 E1 (Bowell) and 47P/Ashbrook-Jackson (Meech and Jewitt 1987). Furthermore, the nearly symmetrical behavior of the *Afρ* curve recalls much more of what is expected by a phase effect than from an outburst, where usually a sudden brightening is followed by a slower fading. The comet displayed also a typical well-developed dust tail, and if dust had a main role in the brightness of the coma, a phase effect of course can be expected. As, in that period, the comet apparently displayed a regular behavior (no evident morphological changes occurred that could indicate transitory events), we concluded that the apparent brightening is better explained by a simple phase effect than by other kinds of possible transitory events. If true, this means that the *Afρ* quantity was indeed nearly constant around 3128 cm for all the observed period (see Figures 4-5).

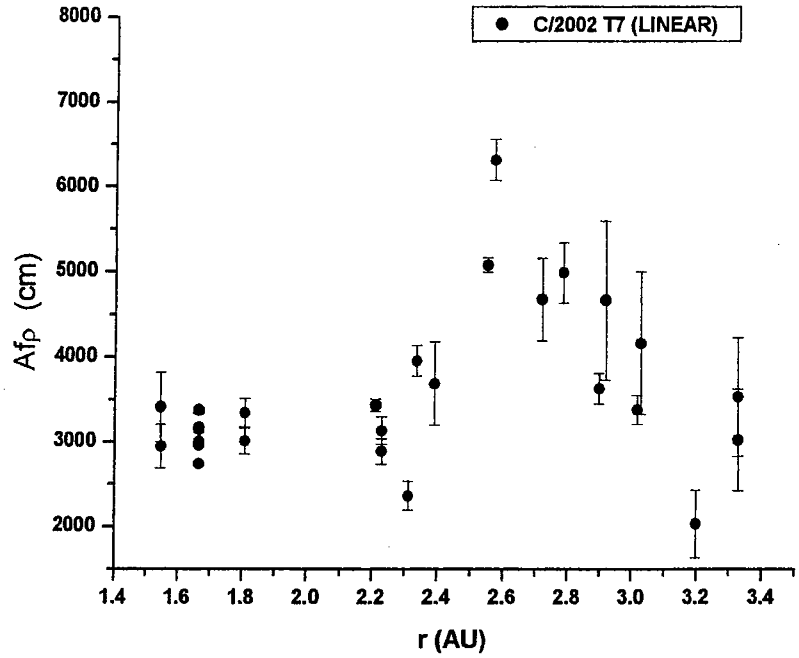
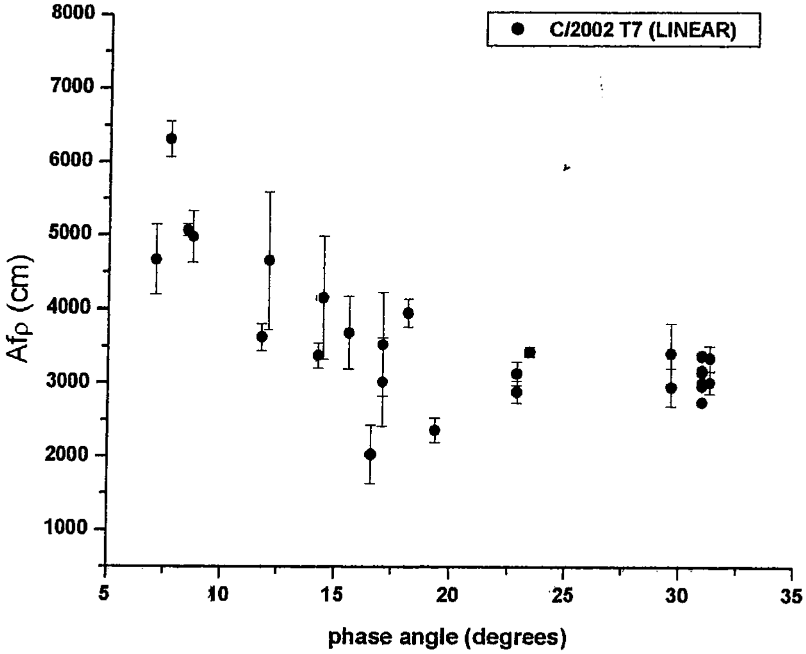


Figure 4 (above). The behavior of comet C/2002 T7 showed an apparent brightening in the pre-perihelion phase with a transitory increment in the Afρ value.

Figure 5 (below). A more-detailed analysis of comet C/2002 T7 showed that the observed brightening is fully compatible with what was expected by a phase effect. The Afρ values show a well-defined dependence upon the phase angle; the trend is in fairly good agreement with what was found for other objects.



◇ ◇ ◇

[text continued from page 245]

C/2001 Q4

Early preliminary results on C/2001 Q4 shows that a great improvement can come from the use of the 647-nm filter, because such filtered data do not suffer from gas contamination. *R* and *I* Cousins-band filters yield data that can be still affected by some amount of gas contamination, especially if a bright comet like C/2001 Q4 is observed at small heliocentric distances. Post-perihelion *Afρ* measurements in the 647-nm band (approximating the Vilnius *S* band) show

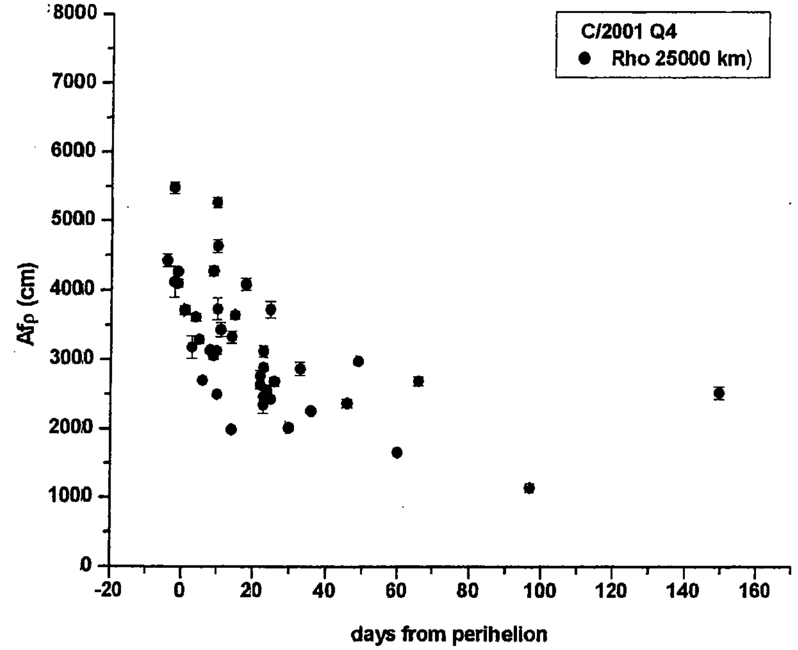


Figure 6. Comet C/2001 Q4 was intensively observed with the narrowband filter centered at 647 nm (10-nm FWHM), close to the S band of the Vilnius system. Unstable weather conditions, and also possible short-term variations, caused some scattering in the data, but the results are quite promising and also show that the gas contamination in broadband data is not negligible for this comet. The Afρ value is nearly constant starting at about five days after perihelion.

◇ ◇ ◇

[text continued from page 246]

a nearly constant behavior close to 2500 cm (see Figure 6), starting from ≈ 5 days after perihelion. Data obtained in the *R* and *I* bands provided values that were a bit higher (by ≈ 30-40%) because of gas contamination. Unfortunately, the quality of the measurements on this comet are not as good as hoped because of the unstable weather conditions during that period. Furthermore, the comet showed remarkable short-term *Afρ* variations (Tozzi 2004), and for this reason it is not easy to accurately check the average quality of the data. Further tests were performed on other bright comets with encouraging results.

Who are we?

The development of this project was supported with the contribution of a several people. Among them, particular thanks go to (in random order): Rolando Ligustri, Giovanni Sostero, Roberto Trabatti, Diego Tirelli, Martino Nicolini, Mauro Facchini, Daniele Carosati, Lorenzo Focardi, Luca Buzzi, Andrea Aletti, Herman Mikuž, Stephane Garro, Carlo Vinante, and many others. Among professional astronomers, we thank in particular Marco Fulle (Trieste Astrophysical Observatory), Gian Paolo Tozzi (Arcetri Observatory), Gyula Szabó (Physics Department and Observatory of Szeged), and Mauro Barbieri (CISAS, Physics Department, Padova University). Further relevant suggestions and contributions came in particular from Michael A'Hearn and Laurent Jorda, whom we met at the last IWCA in Paris.

We often attend informal meetings to discuss results and to improve our program. Meetings were already organized at the Cavezzo Observatory (Modena, Italy), Armenzano Observatory (Assisi, Italy), Rijeka Observatory (Croatia), Crni Vrh Observatory (Slovenia, 2004 June 19-20), Remanzacco Observatory (Udine, Italy), and Arcetri (Firenze, Italy, 2005 May 21-22).

The Italian Comet Section

The Comet Section of the Italian Union of Amateur Astronomers (UAI) is the national reference for comet observers — for visual, photographic, and CCD observations. For many years, a group of active observers coordinated by the Comet Section (all observers interested in comets, including also non-UAI members) and operating mainly with CCDs have been working together under the acronym GOC (Group of Cometary Observers). This group, in collaboration with some professional astronomers, has developed the CARA project.

The main vehicle of information is the webpage (`http://comete.uai.it/`); maintained by Rolando Ligustri, it collects a large number of images and information. The website is in Italian, and because of the great work of continuous upgrading, it has never been fully translated into English. The magnitude estimates (visual and CCD) are collected by Diego Tirelli, who collaborates directly with Rolando Ligustri. Other observers collaborate in various ways to the general activity, for instance:

- Diego Tirelli, Toni Scarmato, and Lorenzo Focardi for data collection and reduction
- Mauro Facchini and Martino Nicolini for CCD image processing
- Roberto Trabatti for software development
- Giovanni Sostero for photometry
- Carlo Vinante for the development of the CARA website

The GOC is a very active working group thanks to an e-mail list that allows daily contacts among observers.

At present, the main activity concerns the development of CCD observations, but some observers operate also in photographic and visual techniques. Some well-known experienced visual observers (like Sando Baroni and Roberto Haver) are still active, but the main difficulty for performing good visual observation is the increasing light pollution. Several regional laws to limit light pollution were approved in Italy, but their effect is not yet so strong as to stop the brightening of the night sky. CCD observations suffer less limitation and can be performed more readily from light-polluted skies than can visual observations, and several CARA observers have acquired much experience with this technique.

Conclusion

The development of the CARA project gives a new tool to amateur astronomers for providing useful data for studying comets, granting support to professional research. Of course, amateur data are not usually be as good as professional data, but the possibility of monitoring a comet for a longer time can help in better tracing its evolution. The project is a work in progress, and we invite all observers interested in it to collaborate both with observing and in the development of the project. This article reports the state of the project around the middle of 2005, including some improvements added after the time of the Paris IWCA meeting. The recent observing campaign on comet 9P/Tempel was a good opportunity for better tests and improvements on both observing and reduction techniques. Recent results and a new updated `Winafrho` software release will be available as time progresses. Information about this will appear at the CARA website as well as in the pages of the *International Comet Quarterly.*

Acknowledgements. We wish to thank all amateur and professional astronomers who have contributed to this project, noting that CARA is essentially a working group. We thank also Michael A'Hearn and Laurent Jorda, who at the IWCA in Paris encouraged us by giving useful suggestions for future development.

REFERENCES

A'Hearn, M. F.; D. G. Schleicher; P. D. Feldman; R. L. Millis; and D. T. Thompson (1984). "Comet Bowell 1980b", *Astron. J.* **89**, 579.

Bessel, M. S. (1990). "UBVRI Passbands", *P.A.S.P.* **102**, 1181.

Boyle, R. P.; A. Kazlauskas; V. Vansevicius; V. Straizys; F. J. Vrba; J. Sudzius; and F. Smriglio (1998). "CCD Photometry of the M67 Cluster in the Vilnius Photometric System", *Baltic Astronomy* **7**, 369-391.

Caldwell, J. A. R.; A. W. J. Cousins; C. C. Ahlers; P. van Wamelen; and E. J. Maritz (1993). "Statistical Relations Between the Photometric Colours of Common Types of Stars in the *UBV(RI)c*, *JHK* and *ubvy* Systems", *SAAO Circulars* **15**, 1.

Fulle, M. (2000). Personal communication.

Fulle, M.; *et al.* (1997). "Dust Environment of Comet Hyakutake C/1996 B2", *Astron. Astrophys.* **324**, 1197.

Fulle, M.; *et al.* (2004). "The dust environment of comet 67P/Churyumov-Gerasimenko", *Astron. Ap.* **422**, 357.

Green, D. W. E., ed. (1997). *ICQ Guide to Observing Comets.*

Meech, K. J.; and D. C. Jewitt (1987). "Observations of Comet P/Halley at minimum phase angle", *Astron. Ap.* **187**, 585.

Mikuž, H.; and B. Dintinjana (1994). "CCD Photometry of Faint Comets", *ICQ* **16**, 131.

Milani, G. (2003a). "Fotometria Cometaria d'apertura in Bande Fotometriche Standard", *Astronomia UAI* **2**, 46.

Milani, G. (2003b). "Metodo per Estrapolare Magnitudini *R* e *I* da Stelle Note", *Astronomia UAI* **2**, 63.

Montgomery, K. A.; L. A. Marschall; and K. A. Janes (1993). "CCD Photometry of the Old Open Cluster M67", *A.J.* **106**, 181.

Tozzi, G. P. (2004). Personal communication.

Weiler M.; *et al.* (2004). "Optical Observations of Comet 67P/Churyumov-Gerasimenko", *Astron. Ap.* **414**, 749.

Φ Φ Φ

2006 COMET HANDBOOK

The *2006 Comet Handbook* is being printed the week after this October issue is being mailed to subscribers, so should follow in the mail about a week later to those readers who have paid to receive the *ICQ*'s annual *Handbook.* The *2006 Comet Handbook* is the 20th edition, with a record size near 160 pages and containing up-to-date orbital elements, magnitude parameters, and ephmerides for some 175 comets predicted to be brighter than mag 21 during the year 2006.

Variable-Aperture-Correction Method in Cometary Photometry

Ignacio Ferrín[1]
Center for Fundamental Physics, University of the Andes, Mérida, Venezuela

Abstract. *The photometric conversion from the m_v (visual, scotopic) to the V-band (CCD + V filter) system, has been calculated using the spectra of comets C/1973 E1 (Kohoutek; O.S. 1973f = 1973 XII), 1P/Halley, and 2P/Encke. I found the following results:* a) *The mean transformation is $V - m_v = -0.026 \pm 0.007$ magnitude, a very small value in comparison with typical measurement errors of 0.3 mag or larger for visual observations.* b) *This result is independent of the intensity of the continuum because the central wavelengths of the two systems are separated by only 120 Å.* c) *The transformation value is even smaller for green-sensitive CCDs.* d) *It is also shown that the result is independent of the sun-comet distance, r.* e) *An "insufficient-photometric-aperture error" has been identified in CCD measurements that may produce values up to 2 magnitudes fainter than "true" total magnitudes, and a "variable-aperture-correction method" is proposed to derive a total magnitude free of this error.*

1. Introduction

In an interesting paper on the CCD photometry of comet C/1995 O1 (Hale-Bopp), Mikuž and Dintinjana (2001) found that V-band observations of faint comets tended to be systematically fainter by 0.5-1 magnitude than visual magnitudes. The explanation they chose for this discrepancy is that the human-eye and V-filter passbands are not the same and thus capture different fluxes. (This fact had been noted earlier by Green 1997, based partly on the Slovenian data). The magnitude difference is in the sense $m_v < V$ (i.e., m_v is brighter than V). A formal numerical analysis has apparently never been made.

The objective of this work is to test this hypothesis and to find a numerical transformation from the m_v (visual, scotopic) system to the V band (CCD + V filter). This discussion rules out some possible explanations put forward to resolve the magnitude discrepancy.

Figures 1 and 2 show published spectra of comets 2P/Encke (Djorgovski and Spinrad 1985) and 1P/Halley (Roettger *et al.* 1990). The first is an example of low dust production (as can be ascertained from the intensity of the continuum), while the second is representative of a high-dust-production comet. Also depicted in these figures are the scotopic bandpass of the eye (Cox 1999), and the V-filter transmission curve (Landolt 1992) multiplied by the sensitivity curve of a typical frontal-illuminated red-sensitive CCD (Howell 2000; McArthur 1999); later on, I consider the case of other CCDs. I have also made use of a spectrum of comet C/1973 E1 (A'Hearn 1975), but I do not consider it necessary to present the plot here because it is intermediate between the other two.

Given the intensity, $I(\lambda)$, of a comet spectrum as a function of wavelength (λ) multiplied by the scotopic and V response functions ϕ_s and ϕ_V, we can find the fluxes by direct integration.

$$F_V = (1/N_V) \int \phi_V(\lambda) I_{\rm comet}(\lambda) \Psi_{\rm CCD}(\lambda) {\rm d}\lambda \tag{1}$$

$$F_s = (1/N_s) \int \phi_s(\lambda) I_{\rm comet}(\lambda) {\rm d}\lambda, \tag{2}$$

where $\Psi_{\rm CCD}$ is the CCD response function.

The area under the curves, $F_s(\lambda)$ and $F_V(\lambda)$ — the transmissions of the scotopic and V passbands (Cox 1999) — are initially normalized to one:

$$(1/N_V) \int \phi_V(\lambda) \Psi_{\rm CCD}(\lambda) {\rm d}\lambda = 1 \tag{3}$$

$$(1/N_s) \int \phi_s(\lambda) {\rm d}\lambda = 1 \tag{4}$$

where N_V and N_s are normalization constants.

---

[1] e-mail address `ferrin@ula.ve`

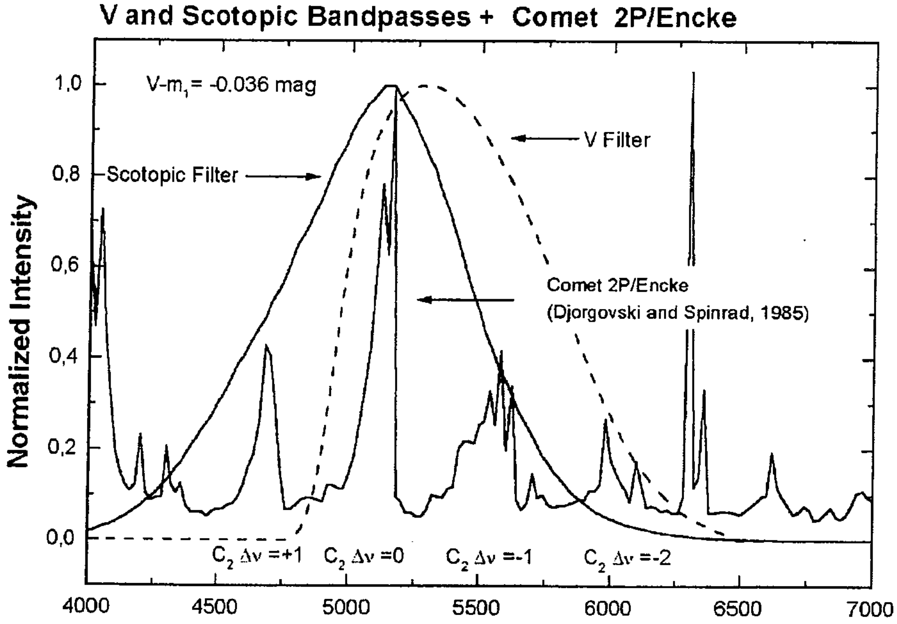


Figure 1

Figure 1 (above). Spectrum of comet 2P/Encke (Djorgovski and Spinrad 1985), with the scotopic and V + CCD response curves. The maximum of the filters has been set to one for clarity, but the calculation was done with the area under the filters normalized to one. Notice the slope and level of the continuum. The identified bands correspond to the C_2 molecule.

Figure 2 (below). Spectrum of comet 1P/Halley (Roettger et al. 1990). Notice the level and slope of the continuum.

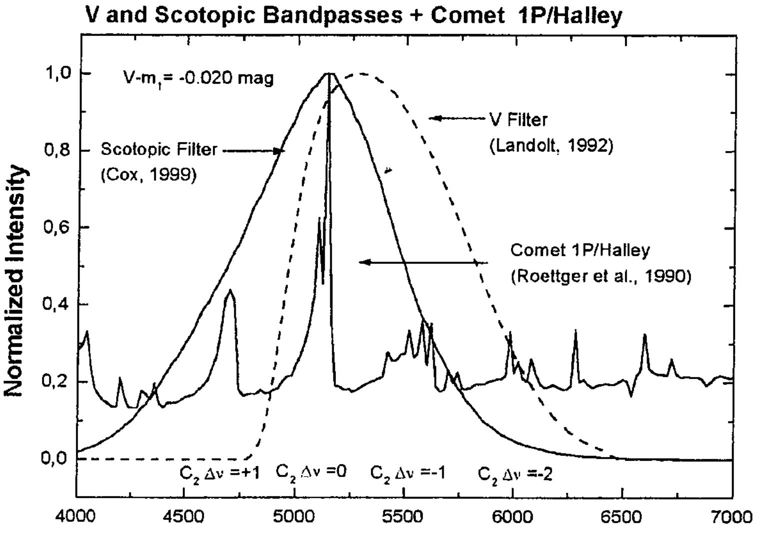


Figure 2

◇ ◇ ◇

[text continued from page 249]

The transformation from one photometric system to the other is then given by:

$$V - m_v = 2.5\log(F_V/F_s) \tag{5}$$

The calculation is performed after sampling each comet spectrum at evenly-spaced 20-Å intervals (yielding 150 total data points), and doing the integrations (equations 1 to 4) as a sum.[2] The results for the three comets are presented in

---

[2] Berry and Burnell (2000) discuss convolutions as summations; the integrals here are the expansion of equation 12.1 of Berry and Burnell, who treat the general case of convolution in one dimension (of which the present case is but just one example). Equation 1 above is simply the

Table 1.

TABLE 1. m_v to V transformation for 3 comets

Comet	V - m_v	Dust (Continuum)
2P/Encke	-0.036	Low
C/1973 E1 (Kohoutek)	-0.021	Intermediate
1P/Halley	-0.020	Large

Mean V - m_v = -0.026 +/- 0.007 mag

From Table 1 it can be concluded that the difference in magnitude found by Mikuž and Dintinjana (2001) can not be due to the different passbands of the visual and CCD V observations, since the mean is so small (in fact it is negligible in comparison with uncertainties of 0.3 magnitude and larger found commonly with visual observations).

II. Influence of the Continuum on the Calculation

If the continuum is higher in the V-band region (i.e., at longer wavelength) than in the scotopic-band region, the V band would register a higher flux, and thus a brighter magnitude, and $V - m_v$ would be more negative. What I find, however, is the reverse: the difference decreases with increasing continuum. I conclude that the different values found in Table 1 are not due to the continuum but to intrinsic differences in the cometary spectra.

The intensity of the continuum cannot affect the result if the continuum is flat, because then the flux would be the same in all the passbands. I located four cometary spectra published in the literature that exhibit flat continua: two independent spectra of comet 2P/Encke (Goraya *et al.* 1986; Djorgovski and Spinrad 1985), the aforementioned spectrum of comet C/1973 E1 (A'Hearn 1975), and a spectrum of comet 8P/Tuttle (1980 XIII; Osborn *et al.* 1990). These spectra were chosen after a search for the best calibrated spectra available in the literature, the criteria being that they have high resolution and good scale in print. Enlarged copies were made of the published spectroscopic plots, and 450 intensity points along each plot were digitized; errors in the processing of these published spectra (due to reading errors and to errors from the filters taken from Cox) are estimated to be on the order of $\sim$ 5 percent.

According to A'Hearn *et al.* (1980), "the continuum reflectivity increases from 4000 to 8000 Å by a factor of 1.5 ± 0.5. The results for comets with weaker continua and the results from studies at even lower spectral resolutions are much less consistent with each other and probably reflects the great difficulty in defining the continuum level". Since the peaks of the V and scotopic bands differ by 120 Å, with V being of longer wavelength, then a change of intensity by a factor f of 1.5 ± 0.5 represents a change of $(120\ \text{Å}/4000\ \text{Å})(2.5 \log f) = -0.013^{+0.013}_{-0.010}$ mag, entirely within the values found in Table 1.

This result and our conclusion can be independently confirmed. The CCD spectrum of 39 comets has been obtained by Fink and Hicks (1996), who divided each spectrum by that of a solar-type comparison star; if the comet continua are simply solar-reflection spectra, then the resulting continua will be flat — as seems to be the case here. This means that the dust is neutral in color, colorless, and that the observed color is due to the sun. Even in those cases in which there is a detectable continuum, the influence in both filters is the same and thus does not affect the m_v-to-V transformation.

Hainaut and Delsanti (2002), give for the color of the sun, $V - R = +0.36$. If I convert this to an intensity using Pogson's equation, I get a factor of 1.39 — in excellent agreement with the value given by A'Hearn *et al.* (1980) of 1.5 ± 0.5 (cited above). Since the two filters V and R are separated by about 1000 Å, and the scotopic and V bands are separated by 120 Å, then a linear interpolation gives the magnitude difference between the scotopic and V bands as 0.043 mag. For a third time, I find such a value so small that it cannot explain the difference found by Mikuž and Dintinjana.

III. Other CCDs

The question also arises as to whether this result is valid for other CCDs. Our calculation was done for a red-sensitive front-illuminated CCD with a V filter. The response curves of several CCDs (Howell 2000; McArthur 1999) show that some back-illuminated CCDs have a sensitivity curve closer to the V band. In this case, the transformation from V to m_v would be even smaller. The same happens for the response curve of Sony CCDs, and for blue-enhanced CCDs. All have response curves closer to the visual band. These response curves imply that the values presented in Table 1 are actually upper limits.

Thus the difference found between the two photometric systems is so small, in comparison with visual errors, that both systems may be taken as identical for most applications.

---

convolution of the V bandpass with the comet spectrum; equation 2 is the same for the scotopic filter. Equations 3 and 4 are normalization constants. Additional useful references on convolution include those by Born and Wolf (1964) and by Lipson and Lipson (1969). Brault and White 1971 also discuss the analysis of spectral lines via convolution.

IV. Influence of Comparison Stars

Green (1997, p. 65) has considered the influence of the color of comparison stars on visual magnitudes. Howarth and Bailey (1980) found the following transformation equation

$$m_v = V + 0.16(B - V), \tag{6}$$

while Stanton (1981) obtained

$$m_v = V + 0.182(B - V) - 0.032, \tag{7}$$

where B and V are the standard (Johnson system) photoelectric broadband-filtered catalogued magnitudes. The two equations give essentially the same numerical values. For the typical range of stars, $-0.2 < B\text{-}V < +1.5$, the maximum difference found with equations (6) and (7) is $-0.07 < m_v\text{-}V < +0.24$. Both studies show that the relationship of m_v to V is dependent upon the color of the comparison star, the value of m_v being much larger for a very red object. However, even the maximum value is not enough to explain Mikuž and Dintinjana's discrepant magnitudes because 'extreme'-colored stars will appear only occasionally. So, what might be the reason for discrepant magnitudes?

V. Influence of Focal Length

In addressing this problem, Mikuž and Dintinjana (2001) found that the best agreement between V and m_v observations took place when they used several short-focal-length lenses coupled with CCDs and a V filter, demonstrating that long focal distance is one of the major culprits of faulty cometary magnitudes. This was already shown for visual magnitudes by rigorous Fourier analysis in Meisel and Morris (1976). The difference that Mikuž and Dintinjana found between m_v and V was negligible for two comets, C/1995 O1 (Hale-Bopp) and 103P/Hartley, using this methodology. The moral of this tale is to use the smallest focal distance possible, sufficient to show the object (Green 1997).

◇ ◇ ◇

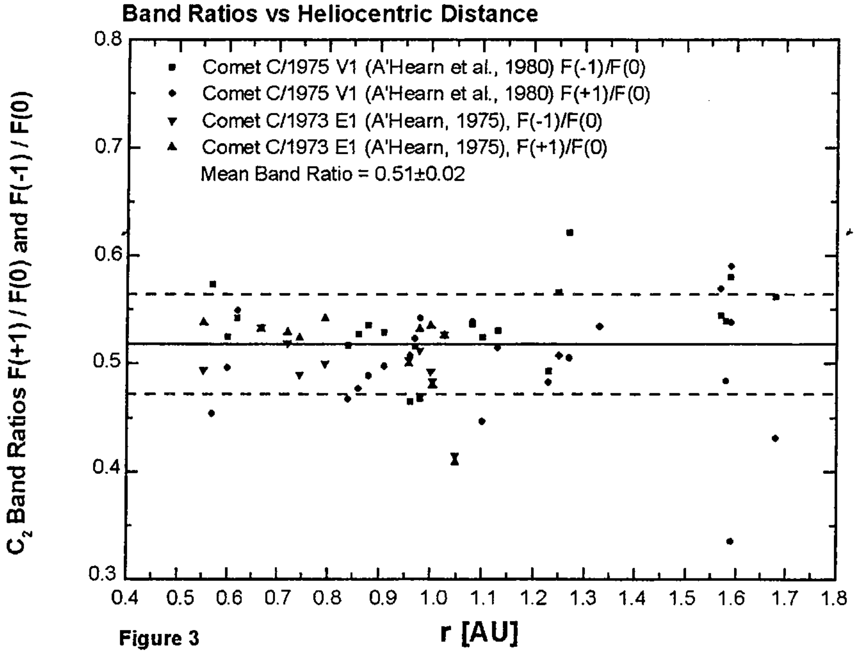


Figure 3

Figure 3. The ratios of the fluxes $F(+1)/F(0)$ and $F(-1)/F(0)$ of the C_2 molecular bands are plotted versus heliocentric distance, r, (A'Hearn 1975; A'Hearn et al. 1980). The flux-ratio points for two comets representing the following C_2 bands are plotted with these symbols: filled squares for comet C/1975 V1, [$\Delta v = -1$]/[$\Delta v = 0$]; filled circles for comet C/1975 V1, [$\Delta v = +1$]/[$\Delta v = 0$]; filled ∇s for C/1973 E1, [$\Delta v = -1$]/[$\Delta v = 0$]; filled Δs for C/1973 E1, [$\Delta v = +1$]/[$\Delta v = 0$]. The solid line is a least-squares fit to the points, representing a mean flux ratio of 0.51 ± 0.02; the slope is 0.002 ± 0.018, meaning that the distribution is flat (so the correlation is zero and the ratio of the C_2-band fluxes is not a function of r). The dashed lines indicate two standard deviations. There is no significant trend with r, and thus $V - m_v$ must also be independent of solar distance.

VI. Dependence on Solar Distance

The visual part of a comet's spectrum that covers the scotopic and V bands is dominated by several C_2 molecular bands, denoted by $\Delta v = +1$, 0, and -1 (see Figure 2). If we denote by $F(+1)$, $F(0)$, and $F(-1)$ the fluxes in those bands, then the ratios $F(+1)/F(0)$ and $F(-1)/F(0)$ must be constant and independent of distance to the sun, because they are fixed by atomic parameters (the transition probabilities between energy levels is determined by quantum mechanics). Interestingly, there is enough observational information to test this hypothesis, too. A'Hearn (1975) and A'Hearn *et al.* (1980) have measured these ratios for comets C/1973 E1 (Kohoutek; O.S. 1973 XII) and C/1975 V1 (West; O.S. 1976 VI). Figure 3 shows the observed flux ratios plotted vs. solar distance, r, in AU. There is no systematic trend with r (from 0.5 to 1.7 AU), and thus I must conclude that this result is independent of solar distance, as expected on physical grounds. Then the transformation $V - m_v$ is also independent of solar distance because the flux captured by the V filter plus CCD and the scotopic bands are mainly influenced by these flux ratios.

VII. Insufficient-CCD-Aperture Error

One of the photometric problems mentioned by Mikuž and Dintinjana (2001) is that there is a discrepancy between the visual and CCD observations that amounts to several magnitudes. It can be deduced from the literature that it is common to use a photometric aperture too small to measure the entire CCD images of comets. Delsemme (1973) solved this problem rigorously for fixed-aperture photometry by integrating the standard Haser model (1957) of the radial gradient of comet brightness. The method advocated here resembles that proposed by Delsemme. It works because the radial intensity of a comet coma falls off more rapidly with distance than the simple 1/radius relationship that one gets from a steady-state flow.

◇ ◇ ◇

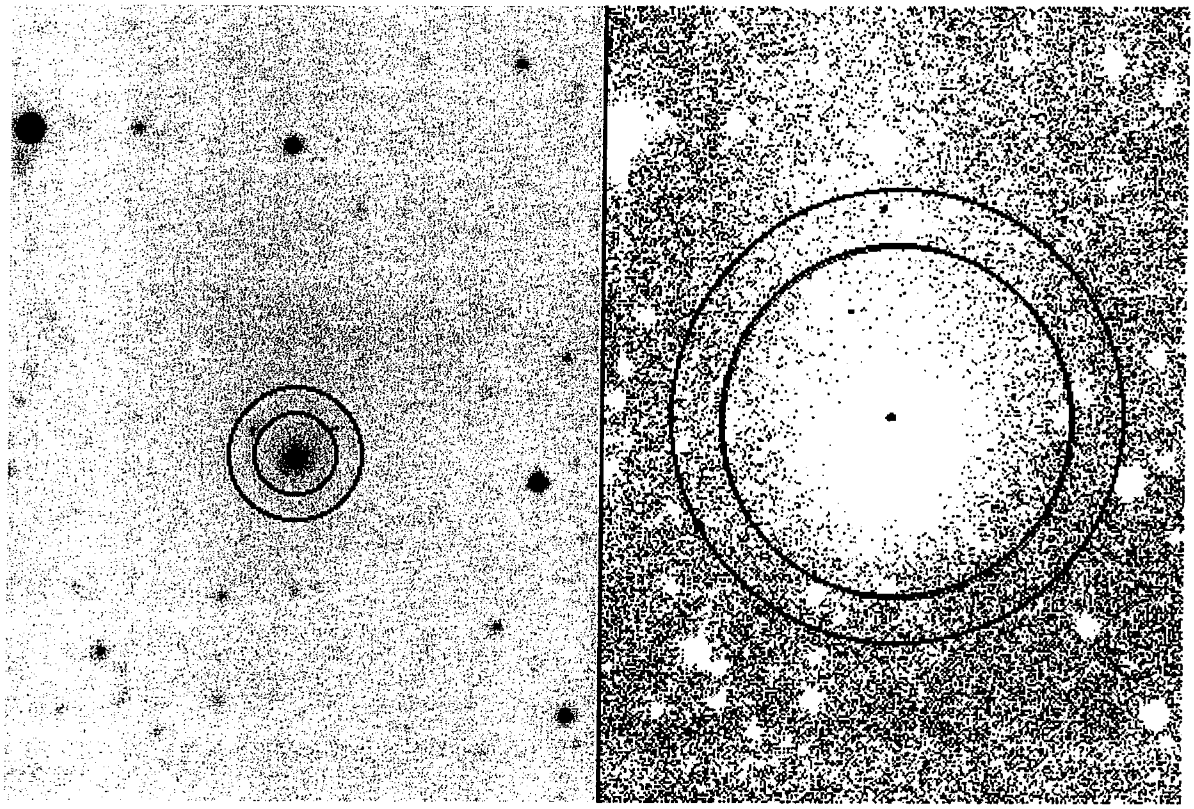


Figure 4. CCD images of comet 62P/Tsuchinshan taken on 2005 March 15 with the 1-m Schmidt telescope of the National Observatory of Venezuela (north is up and east to the left). The left image shows a normal stretching with a 20-pixel aperture radius that seems to be sufficient to extract a total magnitude for the comet. However, a forced stretching shows that the comet extends much father than previously believed — in fact filling an 80-pixel aperture radius (notice that some flux is still left outside in the upper region). The 20-pixel aperture yields a brightness value that is 2 magnitudes fainter than a 130-pixel aperture. Field size: 4'.5 × 6'.3.

◇ ◇ ◇

The problem can be understood by looking at Figure 4, which shows two images of comet 62P/Tsuchinshan taken with the 1-m Schmidt telescope of the National Observatory of Venezuela — from a 3-minute exposure with no filter.

The left image shows the comet rendered with a normal "stretching" of the image.[3] A measuring circle of radius 20 pixels has been drawn, and this circle *seems* to be sufficiently large (with respect to the visible coma) to extract a total magnitude for the comet.

However, a forced stretching of the image (shown on the right side of Figure 4), shows that the comet actually fills the former aperture and that a circle of radius 80 pixels *still leaves some flux outside* (mainly in the upper region of the image).

◇ ◇ ◇

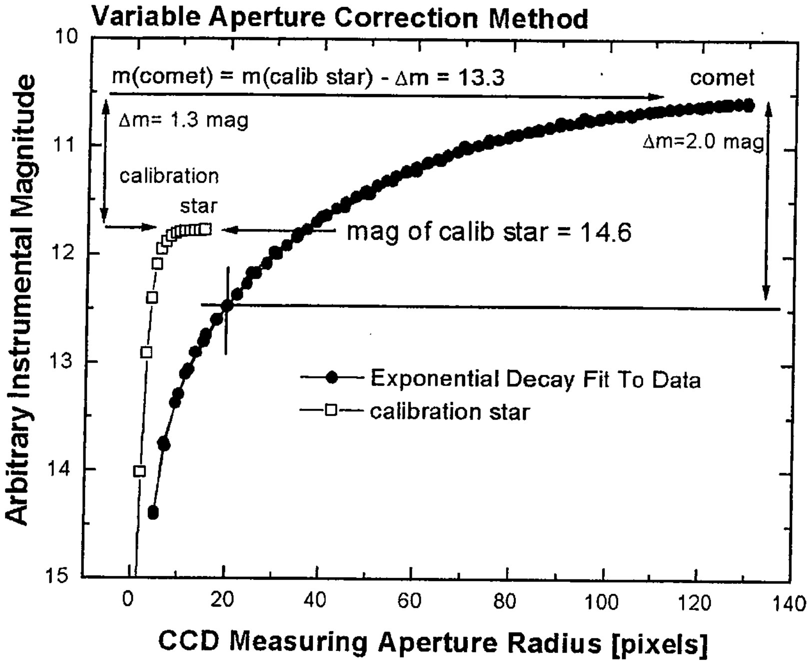


Figure 5. Variable-aperture-correction method. To avoid the Insufficient-CCD-Aperture Error exposed in Figure 4, I propose the use of a variable-aperture-correction method: The magnitude is measured with increasing apertures, and these are plotted in a magnitude-vs.-radius plot. The magnitude extrapolated to infinity is the correct magnitude. This figure shows that an aperture of radius 130 pixels (> 2 minutes of arc) is needed to extract a total magnitude, and this result is for a comet of magnitude 13. The value initially assigned to the reference star is unimportant because what matters is the difference in magnitudes measured from the vertical scale of the plot, Δm. In this example, the star and comet differ by $\Delta m = 1.3$ magnitudes as measured from the plot. Thus, if the reference star is of magnitude 14.6, then the comet must be at mag 13.3.

◇ ◇ ◇

VIII. A Method of Correcting CCD Magnitudes

To avoid the insufficient-CCD-aperture error, I propose the adoption of a variable-aperture-correction method. This consists of measuring the magnitude with increasing apertures and plotting these values to extrapolate them to infinity. Figure 5 shows the instrumental magnitude as a function of measuring aperture for comet 62P/Tsuchinshan. It is concluded that the 20-pixel-radius aperture gives a value 2.0 magnitudes fainter than a 130-pixel aperture. Since the scale of this particular telescope is 1″ (one arcsec) per pixel, this result implies that a measuring aperture larger than 4 minutes of arc (240″) in diameter is needed to extract a true total magnitude.

It is a characteristic of many photometric packages that the measuring aperture does not even reach to 1 minute of arc. It seems that many software providers are thinking of star photometry but are not aware of the needs of cometary astronomers. It would facilitate our work considerably if they would take note of our needs, and provided much larger apertures to be used in cometary photometry. However, David Meisel has alerted me of some software to alleviate this problem: `ImageJ` software is available for a variety of personal computers and analyzes the intensity within an aperture of arbitrary size and shape; it is available free online from the U.S. National Institute of Health (*http://rsb.info.nih.gov/ij*).

To implement the variable-aperture-correction method, take a reference star and assign to it an arbitrary value of magnitude 15. The value assigned is not important because we will apply "differences in magnitude". Measure the reference star with very small photometric apertures (subtracting the sky background in an external circle) and plot these values like in Figure 5. Do the same with the comet now using larger photometric apertures (but still subtracting the sky in a second outer circle). Plot these values, too. Measure from the plot the magnitude difference (extrapolated to infinite

---

[3] Stretching refers to the maximum- and minimum-pixel values selected to display the image. Depending on these values, the image may look deceivingly faint, so I suggest the use of a "forced display" of the image to see the real extent of the comet.

aperture) between the star and the comet; in other words, the "total magnitude" is given by the largest photometric aperture that does not show a further decrease (brightening) in the asymptotic magnitude value. Apply this difference to the comet and derive the real (infinite-aperture) magnitude of the comet using the equation $m_{\text{comet}} = m_{\text{ref}} - \Delta m$, where Δm is measured from the plot. Fitting an exponential decay curve to the data will add in the determination of an asymptotic level. The assumed $f(x)$ can be fit by a linear-least squares procedure — a distinct advantage. Some people are able to just eyeball the place where the curve levels off.

IX. Conclusions

a) The mean photometric transformation between the scotopic m_v and the V photometric systems is $V - m_v = -0.026 \pm 0.007$ from convolution of the spectra of three comets. The value is negligible in comparison with typical visual errors of 0.3 mag or larger, and under some circumstances the two systems may be taken as identical.

b) The value found for the magnitude transformation (Table 1) is independent of the continuum due to dust.

c) The transformation value given in Table 1 can be considered as an upper limit, because other CCDs have response curves that more resemble the visual bandpass.

d) The result is also independent of solar distance, and this is confirmed observationally from 0.50 to 1.70 AU.

e) A variable-aperture-correction method is proposed to avoid the insufficient-aperture error.

Acknowledgements. I thank Daniel Green, David Meisel, Michael A'Hearn, and an anonymous referee for suggestions that helped to improve the text of this paper. I thank the Council for Scientific and Technological Development of the University of the Andes, for support through grant C-1281-04-05-B. The observations mentioned in this work were made at the National Observatory of Venezuela; the help of the night assistants and technicians is also appreciated.

REFERENCES

A'Hearn, M. F. (1975). "Spectrophotometry of Comet Kohoutek (1973f = 1973 XII)", *A.J.* **80**, 861-875.
A'Hearn, M. F.; R. J. Hanisch; and C. H. Thurber (1980). "Spectrometry of Comet West", *A.J.* **85**, 74-80.
Berry, R.; and J. Burnell (2000). *The Handbook of Astronomical Image Processing* (Richmond, VA: Willmann-Bell), p. 333.
Born, M.; and E. Wolf (1964). *Principles of Optics* (Oxford, NY: Pergamon Press), pp. 483-485.
Brault, J. W.; and O. R. White (1971). "The Analysis and Restoration of Astronomical Data via the Fast Fourier Transform", *A.Ap.* **13**, 169.
Cox, A. N., Ed. (1999). *Allen's Astrophysical Quantities* (Berlin: Springer), p. 341.
Delsemme, A. H. (1973). "The Brightness Law of Comets", *Astrophys. Lett.* **14**, 163.
Djorgovski, S.; and H. Spinrad (1985). "Surface Photometry of Comet P/Encke", *A.J.* **90**, 869-876.
Fink, U.; and D. Hicks (1996). "A Survey of 39 Comets Using CCD Spectroscopy", *Ap.J.* **459**, 729-743.
Green, D. W. E. (1997). *ICQ Guide To Observing Comets* (Cambridge, MA: Smithsonian Astrophysical Observatory), pp. 100-103.
Goraya, P. S.; B. B. Sanwal; and B. S. Rautela (1986). "The Spectrum of Periodic Comet Encke", *J.B.A.A.* **96**, 210.
Hainaut, O. R.; and A. C. Delsanti (2002). "Colors of Minor Bodies in the Outer Solar System", *A.Ap.* **389**, 641-664.
Haser, L. (1957). *Bull. Acad. Sci. Belgique* **43**, 740.
Howarth, I. D.; and J. Bailey (1980). *J.B.A.A.* **90**, 265.
Howell, S. B. (2000). *Handbook of CCD Astronomy* (Cambridge University Press).
Landolt, A. U. (1992). "UBVRI Photometric Standard Stars in the Magnitude Range 11.5 < V < 16.0 Around the Celestial Equator", *A.J.* **104**, 340-371.
Lipson, S. G.; and H. Lipson (1969). *Optical Physics* (Cambridge University Press), pp. 52-60.
Meisel, D. D.; and C. S. Morris (1976). in *The Study of Comets*, NASA SP-393, Part I, pp. 410-444.
McArthur, S. B. (1999). "Getting the Right CCD", Photonics Tech Briefs, `http://www.ptbmagazine.com/SEPT99/ptb.ccdfeat999.html`.
Mikuž, H.; and B. Dintinjana (2001). "CCD Photometry of Comet C/1995 O1 (Hale-Bopp)", *ICQ* **23**, 6.
Osborn, W. H.; M. A'Hearn; U. Carsenty; R. Millis; D. Schleicher; P. Birch; H. Moreno; and A. Gutierrez (1990). "Standard Stars for Photometry of Comets", *Icarus* **88**, 228-245.
Roettger, E. E.; P. D. Feldman; M. F. A'Hearn; and M. C. Festou (1990). "Comparison of Water Production Rates from UV Spectroscopy and Visual Magnitudes for Some Recent Comets", *Icarus* **86**, 100-114.
Stanton, R. H. (1981). *JAAVSO* **10**, 1.

Φ Φ Φ

ICQ WEBSITE

The *ICQ* website, `http://www.cfa.harvard.edu/icq/icq.html`, continues to expand. Recent new material added to the website (and linked to from the main webpage) include webpages listing poorly observed comets in need of astrometric and photometric data, comets in recent decades that have been known to have split or known/suspected of falling apart (disappearing), and the brightest comets (brighter than total visual mag 4) seen since 1935 (spacecraft-only comets excluded). There are plans to soon post key articles published in the *ICQ* at the ICQ website, which will be linked to also by the heavily accessed 'Astrophysics Data System' (ADS) bibliographic website.

Marco Cavagna (1958-2005)

The Italian comet observer Marco Cavagna of Milan died at age 47 on August 9 after suffering a stroke. During the 1970s and 1980s, Marco was one of the leading Italian cometary observers, when his name often appeared with published observations together, and he was an enthusiastic contributor to the Italian Comet Section that was born in those years. In the last 20 years, Marco was an active (and co-founding) member of the Sormano Observatory, where, in addition to discovering or co-discovering some two dozen minor planets, he distinguished himself by obtaining accurate astrometric measurements of comets and objects that can pass near the earth.

The 1985-1986 return of comet 1P/Halley was an exciting period for all visual observers and, during the International Halley Watch observing campaign, Marco was the real-time monitoring network coordinator for Italy. Thus, all active Italian observers were quite often in contact with him by phone to share impressions and observations. But the intense astronomical activity of Marco was not only devoted to the direct observations of the sky. For a long time, he was an appreciated lecturer at the Milan Planetarium, and for many years he was a consultant of Commission 20 of the International Astronomical Union. More recently he was among the founders of "Cielobuio" ("Darksky"), an association that works against light pollution and for saving the night sky. His enthusiasm for the group caused him to dedicate one of the minor planets he discovered at Sormano, (13777) 1998 UV$_6$, with the name "Cielobuio".

Marco was one of that kind of skygazers who was moved by a great passion but of few means. While still young, he started to watch the sky with simple binoculars. His great passion appears through his own words when, just after he had obtained a university degree in geology, Marco wrote: ". . . to find comets, to cast a glance at the deep sky, watching Pluto, or the quasar 3C 273 and being aware that the light that is entering your eyes started three billions years earlier, [are among] the more exciting things that can be experienced by an amateur astronomer". Marco contributed 1382 magnitude estimates of variable stars to the AAVSO between 1976 and 1985 (under observer code CIT). He searched for comets with his 20×80 binoculars and used them to make a belated independent discovery of comet C/1980 Y1 (Bradfield; O.S. 1980 XV = 1980t) on 1981 January 5.71 UT, when he found the comet at total visual mag 4.0 with a 0°.3 tail (cf. *IAU Circular* 3561).[1] This discovery by Marco occurred while observing from his home on a very clear evening, and this was his first-ever session at searching for new comets; Marco was so excited that he spent much time calling his friends by telephone to share with the feat of finding a comet on his first night of searching. Even though the comet had been found weeks earlier by Bill Bradfield, Marco was not sad or disappointed as he relished the feeling of having found a "new" bright comet on his own.

Marco inspired many of with his enthusiasm, competence, and "scientific" approach to amateur astronomy — variable stars, comets, lunar occultations and grazes, etc. Marco was a globetrotting astronomer, up and down mountains with his binoculars and a 25-cm *f*/3.9 Dobsonian reflector looking for any transient astronomical phenomena. Some 25 years ago, Marco wrote a column for the local association's bulletin titled "Astrofilia d'assalto" (translated loosely into English as "Aggressive Amateur Astronomy", or more directly as "Amateur-Astronomy Assault"), a name that still today recalls the spirit of this special man when he was young; the column encouraged observation of newly discovered astronomical objects with low-tech equipment in an era when communication was more difficult and visual observations seemed to be more appreciated.

Marco was impressive with his knowledge and his friendliness, even to people meeting him for the first time. He was a cheerful participant in the first International Workshop on Cometary Astronomy held in Selvino, Italy, in 1994, despite his having recently having had to spend some considerable time in hospital for a heart problem. *ICQ* readers may know of Marco's photometric contributions: he had visual magnitude estimates and CCD photometry of more than 50 comets spanning the years 1976-2002 published in the *ICQ* — and available to researchers via the *ICQ* archive. Minor planet (10149) Cavagna was named in his honor in 1999. And it has been recently decided to dedicate the new 60-cm telescope at the Sormano Observatory (scheduled to be completed soon) to Marco.

Piero Sicoli, Giannantonio Milani, Mauro Vittorio Zanotta, Sandro Baroni, and Daniel W. E. Green

Φ Φ Φ

Call for Observations: 2006 Apparition of Comet 41P

Comet 41P/Tuttle-Giacobini-Kresák is perhaps best known for it's tremendous outbursts in brightness during its 1973 apparition, when it rose some four magnitudes in early June (from total visual mag 10.2 to 6.5 in five days, according to John Bortle), and then again some 5-9 magnitudes (the exact rise unknown) in late June or early July to mag 4.5 or so. Comet 41P has long been known to have very steep rises in brightness enroute to perihelion outside of such outbursts, but there are not a lot of really good apparitions with plentiful qualitative photometry.

The best-observed apparitions of comet 41P to date, in terms of photometry, are the 1951 and 1962 apparitions that were followed carefully by Max Beyer, the last two returns to perihelion (1995 and 2001), and to a lesser extent,

---

[1] The comet had moved northward from southern-hemisphere skies around that time, just becoming visible for northern-hemisphere observers, and word had not yet reached many overseas amateur observers of the comet's existence. Marco telexed his discovery to the Central Bureau for Astronomical Telegrams, and Brian Marsden telexed him back that the comet had been found by Bradfield on 1980 Dec. 17. Evidently there were some other independent discoveries of this comet by northern-hemisphere observers, as well (Green 1981, *ICQ* **3**, 9).

the 1973 and 1990 returns. Comet 41P has never been observed photometrically at heliocentric distances $r > 2.32$ AU pre-perihelion, or at $r > 1.68$ AU post-perihelion, due to its very rapid rises and fall-offs in brightness with respect to perihelion. Curiously, the often-scant photometric data on comet 41P seem to suggest a fairly consistent rate of brightening at every apparition from 1907 through 1990 except for (and despite) the 1973 outbursting apparition, the total (visual) magnitude, m_1, apparently well represented by a power-law of the form $m_1 = 10.0 + 5 \log \Delta + 40 \log r$ (where Δ is the geocentric distance in AU).

These power-law parameters (with the absolute magnitude $H \approx 10.0$ and the heliocentric power-law exponent $n \approx 16$) continued to hold for three more apparitions past the 1973 outbursting one — all the way to perihelion in 1995. But the 1995 apparition started to veer well away from the established light curves of comet 41P: the post-perihelion brightness was abnormally high ($H \approx 5.5$ with $n \approx 16$). The comet was fairly well observed for three months at its next return: from Nov. 2000 through Jan. 2001, it rose at a very swift pace (at a rate as high as 90 log r, but notably non-uniformly); its post-perihelion in 2001 was also erratic, but there are too few data to make much out of what happenend.

For periodic comets that do not obviously split into multiple nuclei/components but still veer in complex manner from the standard power-law formula from apparition to apparition (and often within single apparitions), the explanation is probably buried in combinations of the nucleus rotation rate and variation in surface-ice sublimation areas and rates. Other such notable comets with highly problematic light curves include 2P/Encke, 6P/d'Arrest, and 10P/Tempel. As total-magnitude data still compose the vast majority of historical data (spanning numerous apparitions) on comets such as 41P, there will continue to be considerable value in careful monitoring of comets' total brightness; such data should ultimately help in analyzing the complexities of cometary brightness.

The 2006 apparition of comet 41P is a rather good one geometrically, particularly for northern-hemisphere observers. All cometary photometrists are encouraged to make an extensive campaign of observing this comet on every possible night — this being a comet where night-to-night variations are more prominent than in most comets. Both visual and CCD total magnitudes are encouraged. It is hoped that more photometric data can be compiled of comet 41P at the 2006 apparition than at all the previous apparitions combined, starting as early as possible (the comet will likely become visible via amateur CCD instrumentation as early as February 2006), extending at least into July or August.

As with all photometry of faint comets (fainter than mag 18 or 19), observers are strongly encouraged to send full reports of negative observations to the *ICQ* for publication and archiving. It can be just as useful to know that a comet was not observed as knowing that it was successfully observed — provided that the observer provide all of the same observing information as would be given with a positive detection, with a limiting stellar magnitude provided along with some indication (in descriptive text) of the line-of-variation that was searched (stating also the source and epoch of the orbital elements, and whether the observed used a search ephemeris that allowed for planetary perturbations and/or specified nongravitational-force parameters). — *D. W. E. Green*

Φ Φ Φ

COMETS FOR THE VISUAL OBSERVER IN 2006

Alan Hale
Southwest Institute for Space Research

Somewhat in contrast to the past few years, at this writing (late Sept. 2005) there are no known inbound long-period comets that are expected to reach naked-eye brightness during 2006, although some fainter objects should be detectable with moderate-size visual telescopes. Meanwhile, one short-period comet may reach naked-eye visibility during mid-2006, and several other short-period objects should also become visually accessible during the course of the year.

Perihelion information (utilizing the most recently computed orbits at the time of this writing) for the comets discussed below is given in Table 1, in chronological order of perihelion passage. Ephemerides are available in the *2006 Comet Handbook* published by the *ICQ*.

Long-Period Comets

C/2004 B1

Discovered by the LINEAR project as long ago as January 2004, this comet has recently emerged into the morning sky following conjunction with the sun in mid-2005. At this writing, no visual observations have yet been reported, and the available CCD reports suggest it may be running some $\sim$ 2 magnitudes fainter than the original expectation for this time. The comet enters southern circumpolar skies by the beginning of October 2005 and remains there through year's end, and presumably should be visually observed (at total magnitude $m_1 \sim 11$?) during the last couple of months of the year.

By the beginning of 2006 the comet is traveling northward, but passes conjunction (some 24° south of the sun) in late January. Southern-hemisphere observers should be able to keep C/2004 B1 under observation at it emerges into the morning sky, and by the latter part of March it should also be accessible from the northern hemisphere. The comet is nearest Earth ($\Delta = 1.35$ AU) in late May and is at opposition in early June, and should be near its peak brightness ($m_1 \sim 10$?) during April and May. Afterwards, C/2004 B1 may remain visually detectable until perhaps August.

TABLE 1.
PERIHELION INFORMATION FOR POTENTIALLY VISUAL COMETS IN 2006

Designation/Name	T (TT)	q (AU)
29P/Schwassmann-Wachmann	2004 July 10.8	5.72
60P/Tsuchinshan	2005 Dec. 24.1	1.77
C/2004 B1 (LINEAR)	2006 Feb. 7.9	1.60
C/2005 E2 (McNaught)	2006 Feb. 23.54	1.52
C/2003 WT_{42} (LINEAR)	2006 Apr. 10.77	5.19
71P/Clark	2006 June 7.21	1.56
73P/Schwassmann-Wachmann	2006 June 6.95	0.94
41P/Tuttle-Giacobini-Kresák	2006 June 11.3	1.05
45P/Honda-Mrkos-Pajdušáková	2006 June 29.8	0.53
4P/Faye	2006 Nov. 15.4	1.67
P/1991 V1 (Shoemaker-Levy)	2006 Nov. 17.0	1.13
76P/West-Kohoutek-Ikemura	2006 Nov. 19.6	1.60

◇ ◇ ◇

C/2005 E2

This comet was at opposition in July 2005 and is presently visually detectable at $m_1 \sim 12$. During the remainder of 2005, it will be easily accessible in the evening sky and should brighten to $m_1 \sim$ 10-11 by year's end. C/2005 E2 should remain visible for the first 2-3 months of 2006, although the elongation will start to become small (becoming < 40° in mid-January and < 30° by mid-March); it may brighten by approximately a half-magnitude during this time. The comet then disappears into sunlight and will probably be too faint for visual observations when it emerges into the morning sky around September.

C/2003 WT_{42}

This distant comet has recently emerged into the morning sky and is at opposition in mid-February 2006. C/2003 WT_{42} may reach $m_1 \sim 14$ during the last few months of 2005 and first few months of 2006; it remains near $\delta \sim +50°$ throughout this time, and thus observations will primarily be limited to northern-hemisphere observers.

Brighter Short-Period Comets

73P/Schwassmann-Wachmann

The chief cometary highlight of 2006 will probably be this object. Comet 73P was originally discovered in 1930 and passed 0.062 AU from the earth in late May of that year, reaching $m_1 \sim 7$ in the process. Despite an orbital period of 5.4 years, 73P was not observed again until its 1979 return. In 1995, this comet underwent a nuclear splitting into at least five fragments (although only four were detected at the time), and this was accompanied by a dramatic brightness increase that saw the comet reach $m_1 \sim 5$ despite generally unfavorable viewing circumstances. At the subsequent (and very unfavorable) return in 2000-2001, three components (the presumed primary, component C, as well as two fainter ones, B and E) were detected, and the comet was still unexpectedly bright: component C was observed as being at $m_1 \sim$ 11-12 (see the paper by Sekanina on 73P on page 225 of this issue of the *ICQ*).

In 2006, the comet makes another very close approach to the earth, akin to that in 1930: the primary component C passes 0.073 AU from Earth on May 13. Brightness predictions must be considered uncertain in light of the comet's recent behavior — but, if it retains its brightness from 2000-2001, it may be as bright as $m_1 \sim$ 3-4 for a few days around this time. Unfortunately, the moon is full on May 13, and since 73P is located in the morning sky, observations for the next several days after its close passage by Earth will be strongly affected by moonlight.

The perihelion information in Table 1 is for component C. Component B, the faintest of the three observed in 2000-2001, passes perihelion 0.80 day later and passes 0.064 AU from Earth on May 14; if its brightness is similar to that of 2000-2001 it should reach $m_1 \sim$ 6-7. Component E passes perihelion 2.20 days after C, and passes 0.050 AU from Earth on May 17; its brightness in 2000-2001 suggests it may reach $m_1 \sim 5$. Whether either of these companion objects still exist, let alone whether they reach these brightnesses, remains to be seen.

Brightness predictions for component C throughout the entire apparition must be considered problematical. If the 2000-2001 brightness is used as a rough guide, the comet should become visually detectable by perhaps February, and remain observable until perhaps September.

71P/Clark

This comet's 2006 return is very similar to those of 1973 (discovery), 1984, and 1995 — during which 71P generally reached a peak brightness near $m_1 \sim 11$, and thus a similar brightness may be expected this time. It should become visually detectable by early April, is at opposition (and near peak brightness) in mid-June, and should remain observable until about September. The comet is near $\delta \sim -40°$ throughout the brightest portion of its apparition, and thus southern-hemisphere observers are favored.

41P/Tuttle-Giacobini-Kresák

This comet remains in the evening sky, between an elongation of 60° and 70°, throughout the brightest part of its 2006 apparition. Brightness predictions for this return are uncertain, as the comet has been unexpectedly bright at the previous two returns (in 1995 and 2000-2001); furthermore, it exhibited unusual brightness fluctuations, indicative of minor outbursts, at both returns. If the peak brightness exhibited at its most recent return is repeated this time, the comet may become as bright as $m_1 \sim 8$ sometime during May and/or June. It could, certainly, be significantly fainter — or, conceivably, brighter — than this.

This particular comet, in fact, has had a long history of unusual brightness behavior (see the following article by Dan Green calling for observations). In 1973, 41P underwent two very large outbursts (9-10 magnitudes) that briefly brought it to $m_1 \sim$ 4-5. Curiously, the current return is rather similar to that of 1973, the perihelion date being only twelve days later than that of the earlier return.

45P/Honda-Mrkos-Pajdušáková

The 2006 return of this comet is very unfavorable, with the comet remaining on the opposite side of the sun from the earth throughout the apparition. Observers in the southern hemisphere may be able to observe 45P at a small elongation in the morning sky between mid-May and mid-June, with the comet's perhaps reaching $m_1 \sim$ 9-10 by the time it disappears completely into sunlight.

In contrast to the present return, this comet's subsequent two returns are very favorable, and each will feature a close approach to the earth: 0.060 AU on 2011 August 15 and 0.086 AU on 2017 February 11.

4P/Faye

This comet's 2006 return is very favorable, with opposition occurring slightly over two weeks before perihelion passage. It should become visually observable ($m_1 \sim$ 12-13) by July or August and should remain detectable until perhaps February 2007. Based upon its brightness at recent returns, 4P should reach a peak brightness of $m_1 \sim$ 9-10 around perihelion.

Other Short-Period Comets

29P/Schwassmann-Wachmann

This comet has been unusually active for the past several years — in fact, in almost a state of continuous outburst during its 2002-2003, 2003-2004, and 2004-2005 viewing seasons. Somewhat in contrast, the current viewing season has been rather quiet, with only one small outburst (to $m_1 \sim 13.5$ in early September 2005) having occurred as of this writing. Comet 29P is at opposition in late October 2005, and thereafter remains accessible in the evening sky until March 2006. Following conjunction, it again emerges into the morning sky by the end of June, is at opposition in late November, and then is in the evening sky through the first several months of 2007. As always, 29P should be monitored for any outburst activity.

60P/Tsuchinshan

The visual observation record of this comet is very spotty. Nevertheless, the viewing circumstances at the present return are relatively favorable, the comet being at opposition in early March 2006 — some 2.5 months after perihelion passage. It may become visually detectable during the first few months of 2006, especially if there is any post-perihelion asymmetry in its light curve, but 60P is unlikely to become any brighter than $m_1 \sim$ 13-14. As of this writing, the comet in unrecovered, but this should be taking place within the near future.

P/1991 V1

This comet passed 0.22 AU from the earth and was observed at $m_1 \sim 11$ during its discovery return in 1991, but was missed at its unfavorable return in 1999. The 2006 return is moderately favorable, although less so than that of 1991 (opposition's taking place in late June, and closest approach to Earth, $\Delta = 0.77$ AU, taking place in late November). If the comet maintains the same brightness as in 1991, it should reach a peak brightness of $m_1 \sim 13$ around the time of perihelion and closest approach to Earth.

76P/West-Kohoutek-Ikemura

This comet is at opposition in late January 2007, and is well placed for observation during the last two to three months of 2006. Based upon its brightness at recent returns, 76P should achieve a peak brightness of $m_1 \sim$ 12-13 in December.

Φ Φ Φ

CORRIGENDUM

- In the January 2005 issue (No. 133), page 29, the observation of comet 78P/Gehrels by observer `MIY01` made on 2004 Nov. 16.66 UT is to be deleted (it belongs to comet 32P and is published as such in this issue).

Photometry of Deep-Sky Objects

This is the second batch of photometric data on deep-sky objects that we are publishing, representing data that have been contributed to the *ICQ* by photometric observers of comets for the ultimate purpose of learning more about the inherent problems and uncertainties in determining the brightness of extended celestial objects (see the discussions in *ICQ* **16**, 129, and **26**, 3. So the following data extend the tabulation begun in the April 1998 issue (*ICQ* **20**, 98). The observer codes used below are defined in the key to observers listed under "Tabulation of Comet Observations" later in this issue. All comet observers are urged to contribute to this project, for the analyses of these data may produce useful information regarding the techniques and other issues related to particular observers. — D. W. E. Green

Descriptive Information, to complement the Tabulated Data (all times UT):

◇ *NGC 1952 = M1* ⟹ 1998 Dec. 16.04-16.05: eight comparison stars spanning mag 7.9-8.9 [PER01].

◇ ◇ ◇

Visual Data

NGC 1952 = M1

DATE (UT)	N	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
1998 12 16.04		S	8.3	TJ	10.0	B		14	& 5	4			PER01
1998 12 16.04		M	8.5	TJ	10.0	B		14	& 5	4			PER01
1998 12 16.04		B	8.6	TJ	10.0	B		14	& 5	4			PER01
1998 12 16.05		S	8.2	TJ	3.4	B		9	& 3	7			PER01
1998 12 16.05		M	8.3	TJ	3.4	B		9	& 3	7			PER01

NGC 6356

DATE (UT)	N	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
2005 08 06.92		M	8.6	S	25.5	L	5	60	3	4			MAR02
2005 08 28.92		B	8.4	TI	25.5	L	5	39	2.5	4			MAR02
2005 08 30.90		M	8.7	TI	25.5	L	5	39	> 2	3/			MAR02
2005 09 01.85		M	8.7	TI	25.5	L	5	39	2	4			MAR02
2005 09 02.87		M	8.9	TI	25.5	L	5	39	4	3			MAR02
2005 09 05.87		M	8.8	TI	25.5	L	5	39	3	3/			MAR02
2005 09 08.90		S	8.8	TI	25.5	L	5	39	3	3			MAR02
2005 09 26.83		M	9.2	TI	25.5	L	5	39	2	4			MAR02
2005 09 30.82		M	9.0	TI	25.5	L	5	39	2	4			MAR02
2005 10 01.88		M	8.6	TI	44.5	L	5	65	2	3			MAR02
2005 10 01.88		M	8.7	TI	44.5	L	5	65	1.5	3/			SAN04

NGC 6712

DATE (UT)	N	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
2005 08 06.93		S	8.2	S	25.5	L	5	60	4	3/			MAR02
2005 08 28.94		M	9.1	TI	25.5	L	5	39	4.5	4/			MAR02
2005 08 30.91		S	9.0	TI	25.5	L	5	39	4.5	2/			MAR02
2005 09 01.86		M	9.0	TI	25.5	L	5	39	5	3			MAR02
2005 09 02.88		S	8.5	TI	25.5	L	5	39	6	2			MAR02
2005 09 03.98		M	9.0	TI	44.5	L	5	65	2.5	5			SAN04
2005 09 03.98		M	9.1	TI	44.5	L	5	65	4	2/			MAR02
2005 09 05.87		M	9.0	TI	25.5	L	5	39	5	3			MAR02
2005 09 08.91		M	8.9	TI	25.5	L	5	39	5	3			MAR02
2005 09 26.83		S	9.0	TI	25.5	L	5	39	4	2/			MAR02
2005 09 30.82		M	9.0	TI	25.5	L	5	39	4	3			MAR02
2005 10 01.89		M	9.0	TI	44.5	L	5	65	2	2/			MAR02
2005 10 01.89		M	9.1	TI	44.5	L	5	65	2	3			SAN04

NGC 6760

DATE (UT)	N	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
2005 08 06.94		M	8.8	S	25.5	L	5	60	4	3			MAR02
2005 08 28.94		S	9.0	TI	25.5	L	5	39	3	2/			MAR02
2005 08 30.92		S	9.5	TI	25.5	L	5	39	3	1/			MAR02
2005 09 01.86		S	8.8	TI	25.5	L	5	39	6	2			MAR02
2005 09 03.98		M	9.1	TI	44.5	L	5	65	3	3/			MAR02

NGC 6760 [cont.]

DATE (UT)	N	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
2005 09 03.98		M	9.3	TI	44.5	L	5	65	3	4			SAN04
2005 09 05.88		S	8.7	TI	25.5	L	5	39	4	2/			MAR02
2005 09 08.91		S	9.0	TI	25.5	L	5	39	4	1/			MAR02
2005 09 30.83		S	9.1	TI	25.5	L	5	39	4	1/			MAR02
2005 10 01.89		M	8.9	TI	44.5	L	5	65	5	3/			MAR02

NGC 6934

DATE (UT)	N	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
2005 08 06.94		S	8.7	S	25.5	L	5	60	2	5			MAR02
2005 08 28.95		M	9.1	TI	25.5	L	5	39	2	7			MAR02
2005 08 30.92		B	9.5	TI	25.5	L	5	39	2	5/			MAR02
2005 09 01.86		M	9.1	TI	25.5	L	5	39	2.5	6			MAR02
2005 09 03.99		M	9.5	TI	44.5	L	5	65	2.5	4			SAN04
2005 09 03.99		M	9.6	TI	44.5	L	5	65	2.5	6			MAR02
2005 09 05.88		M	8.6	TI	25.5	L	5	39	2.5	7			MAR02
2005 09 08.91		M	9.4	TI	25.5	L	5	39	2.5	6/			MAR02
2005 09 30.83		M	8.9	TI	25.5	L	5	39	2	7			MAR02
2005 10 01.88		M	8.8	TI	44.5	L	5	65	2	5/			MAR02
2005 10 01.88		M	9.0	TI	44.5	L	5	65	2	5			SAN04

NGC 7078 = M15

DATE (UT)	N	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
2005 08 06.95		B	7.1	S	25.5	L	5	60	5	6/			MAR02
2005 08 28.95		M	6.7	S	25.5	L	5	39	5	5/			MAR02
2005 08 30.93		M	7.3	S	25.5	L	5	39	5	6/			MAR02
2005 09 01.87		M	7.7	S	25.5	L	5	39	6	5/			MAR02
2005 09 04.00		M	7.8	S	44.5	L	5	65	5	5			MAR02
2005 09 04.00		M	8.1	S	44.5	L	5	65	8	5			SAN04
2005 09 05.88		M	7.7	S	25.5	L	5	39	5	5/			MAR02
2005 09 08.92		M	7.6	S	25.5	L	5	39	6	5			MAR02
2005 09 26.84		M	7.3	S	25.5	L	5	39	6	5			MAR02
2005 09 30.83		M	7.2	S	25.5	L	5	39	7	5			MAR02
2005 10 01.91		M	7.0	S	44.5	L	5	65	5	5			SAN04
2005 10 01.91		M	7.3	S	44.5	L	5	65	6	5/			MAR02

◇ ◇ ◇

CCD Data

NGC 221 = M32

DATE (UT)	n	M	MAG.	RF	AP.	T	f/	EXP.	COMA	DC	TAIL	PA	APERTUR	Chp	Sfw	C	P	Cam	OBS.
2004 08 04.99	d	C	7.9	LB	6.3	M	8	a180	> 5				C 3.95m	K40	GAI	5	*	ST7	SRB
2004 08 04.99	d	C	8.1	LB	6.3	M	8	a180	> 5				C 2.00m	K40	GAI	5	*	ST7	SRB
2004 08 04.99	d	C	8.5	LB	6.3	M	8	a180	> 5				C 1.00m	K40	GAI	5	*	ST7	SRB
2004 08 04.99	d	C	8.8	LB	6.3	M	8	a180	> 5				C 7.90m	K40	GAI	5	*	ST7	SRB
2004 08 04.99	d	C	8.8	LB	6.3	M	8	a180	> 5				C 9.85m	K40	GAI	5	*	ST7	SRB
2004 08 04.99	d	C	9.2	LB	6.3	M	8	a180	> 5				C 0.50m	K40	GAI	5	*	ST7	SRB
2004 09 01.98	d	C	7.9	LB	6.3	M	8	a300	> 5				C 7.90m	K40	GAI	5	*	ST7	SRB
2004 09 01.98	d	C	8.0	LB	6.3	M	8	a300	> 5				C 3.95m	K40	GAI	5	*	ST7	SRB
2004 09 01.98	d	C	8.2	LB	6.3	M	8	a300	> 5				C 2.00m	K40	GAI	5	*	ST7	SRB
2004 09 01.98	d	C	8.6	LB	6.3	M	8	a300	> 5				C 1.00m	K40	GAI	5	*	ST7	SRB
2004 09 01.98	d	C	9.4	LB	6.3	M	8	a300	> 5				C 0.50m	K40	GAI	5	*	ST7	SRB
2004 09 02.95	d	C	7.9	LB	6.3	M	8	a300	> 5				C 7.90m	K40	GAI	5	*	ST7	SRB
2004 09 02.95	d	C	8.0	LB	6.3	M	8	a300	> 5				C 3.95m	K40	GAI	5	*	ST7	SRB
2004 09 02.95	d	C	8.2	LB	6.3	M	8	a300	> 5				C 2.00m	K40	GAI	5	*	ST7	SRB
2004 09 02.95	d	C	8.7	LB	6.3	M	8	a300	> 5				C 1.00m	K40	GAI	5	*	ST7	SRB
2004 09 02.95	d	C	9.4	LB	6.3	M	8	a300	> 5				C 0.50m	K40	GAI	5	*	ST7	SRB
2004 09 06.93	d	C	7.9	LB	6.3	M	8	a300	> 5				C 7.90m	K40	GAI	5	*	ST7	SRB
2004 09 06.93	d	C	8.0	LB	6.3	M	8	a300	> 5				C 3.95m	K40	GAI	5	*	ST7	SRB
2004 09 06.93	d	C	8.2	LB	6.3	M	8	a300	> 5				C 2.00m	K40	GAI	5	*	ST7	SRB
2004 09 06.93	d	C	8.6	LB	6.3	M	8	a300	> 5				C 1.00m	K40	GAI	5	*	ST7	SRB

NGC 221 = M32 [cont.]

DATE (UT)	n	M	MAG.	RF	AP.	T	f/	EXP.	COMA	DC	TAIL	PA	APERTUR	Chp	Sfw	C	P	Cam	OBS.
2004 09 06.93	d	C	9.3	LB	6.3	M	8	a300	> 5				C 0.50m	K40	GAI	5	*	ST7	SRB
2004 09 08.97	d	C	7.9	LB	6.3	M	8	a300	> 5				C 7.90m	K40	GAI	5	*	ST7	SRB
2004 09 08.97	d	C	8.0	LB	6.3	M	8	a300	> 5				C 3.95m	K40	GAI	5	*	ST7	SRB
2004 09 08.97	d	C	8.2	LB	6.3	M	8	a300	> 5				C 2.00m	K40	GAI	5	*	ST7	SRB
2004 09 08.97	d	C	8.7	LB	6.3	M	8	a300	> 5				C 1.00m	K40	GAI	5	*	ST7	SRB
2004 09 08.97	d	C	9.4	LB	6.3	M	8	a300	> 5				C 0.50m	K40	GAI	5	*	ST7	SRB

NGC 1952 = M1

DATE (UT)	n	M	MAG.	RF	AP.	T	f/	EXP.	COMA	DC	TAIL	PA	APERTUR	Chp	Sfw	C	P	Cam	OBS.
2004 09 01.99	d	C	7.9	LB	6.3	M	8	a600	> 6.5				C 7.90m	K40	GAI	5	*	ST7	SRB
2004 09 01.99	d	C	8.1	LB	6.3	M	8	a600	> 6.5				C 3.95m	K40	GAI	5	*	ST7	SRB
2004 09 01.99	d	C	9.0	LB	6.3	M	8	a600	> 6.5				C 2.00m	K40	GAI	5	*	ST7	SRB
2004 09 01.99	d	C	10.2	LB	6.3	M	8	a600	> 6.5				C 1.00m	K40	GAI	5	*	ST7	SRB
2004 09 01.99	d	C	11.6	LB	6.3	M	8	a600	> 6.5				C 0.50m	K40	GAI	5	*	ST7	SRB
2004 09 08.98	d	C	8.2	LB	6.3	M	8	a600	> 6.5				C 7.90m	K40	GAI	5	*	ST7	SRB
2004 09 08.98	d	C	8.3	LB	6.3	M	8	a600	> 6.5				C 3.95m	K40	GAI	5	*	ST7	SRB
2004 09 08.98	d	C	9.2	LB	6.3	M	8	a600	> 6.5				C 2.00m	K40	GAI	5	*	ST7	SRB
2004 09 08.98	d	C	10.5	LB	6.3	M	8	a600	> 6.5				C 1.00m	K40	GAI	5	*	ST7	SRB
2004 09 08.98	d	C	11.8	LB	6.3	M	8	a600	> 6.5				C 0.50m	K40	GAI	5	*	ST7	SRB

NGC 6934

DATE (UT)	n	M	MAG.	RF	AP.	T	f/	EXP.	COMA	DC	TAIL	PA	APERTUR	Chp	Sfw	C	P	Cam	OBS.
2004 07 19.96	d	C	8.2	LB	6.3	M	8	a300	> 3.5				C 7.90m	K40	GAI	5	*	ST7	SRB
2004 07 19.96	d	C	8.5	LB	6.3	M	8	a300	> 3.5				C 3.95m	K40	GAI	5	*	ST7	SRB
2004 07 19.96	d	C	8.8	LB	6.3	M	8	a300	> 3.5				C 2.00m	K40	GAI	5	*	ST7	SRB
2004 07 19.96	d	C	9.3	LB	6.3	M	8	a300	> 3.5				C 1.00m	K40	GAI	5	*	ST7	SRB
2004 07 21.94	d	C	8.3	LB	6.3	M	8	a180	> 3.5				C 5.90m	K40	GAI	5	*	ST7	SRB
2004 07 21.94	d	C	8.6	LB	6.3	M	8	a180	> 3.5				C 2.95m	K40	GAI	5	*	ST7	SRB
2004 07 21.94	d	C	8.8	LB	6.3	M	8	a180	> 3.5				C 2.00m	K40	GAI	5	*	ST7	SRB
2004 07 21.94	d	C	9.4	LB	6.3	M	8	a180	> 3.5				C 1.00m	K40	GAI	5	*	ST7	SRB
2004 08 04.91	d	C	8.2	LB	6.3	M	8	a300	> 3.5				C 5.90m	K40	GAI	5	*	ST7	SRB
2004 08 04.91	d	C	8.5	LB	6.3	M	8	a300	> 3.5				C 2.95m	K40	GAI	5	*	ST7	SRB
2004 08 04.91	d	C	8.8	LB	6.3	M	8	a300	> 3.5				C 2.00m	K40	GAI	5	*	ST7	SRB
2004 08 04.91	d	C	9.3	LB	6.3	M	8	a300	> 3.5				C 1.00m	K40	GAI	5	*	ST7	SRB

NGC 7078 = M15

DATE (UT)	n	M	MAG.	RF	AP.	T	f/	EXP.	COMA	DC	TAIL	PA	APERTUR	Chp	Sfw	C	P	Cam	OBS.
2004 07 19.93	d	C	6.0	LB	6.3	M	8	a300	>10				C11.85m	K40	GAI	5	*	ST7	SRB
2004 07 19.93	d	C	6.1	LB	6.3	M	8	a300	>10				C 7.90m	K40	GAI	5	*	ST7	SRB
2004 07 19.93	d	C	6.3	LB	6.3	M	8	a300	>10				C 3.95m	K40	GAI	5	*	ST7	SRB
2004 07 19.93	d	C	6.7	LB	6.3	M	8	a300	>10				C 2.00m	K40	GAI	5	*	ST7	SRB
2004 07 19.93	d	C	7.3	LB	6.3	M	8	a300	>10				C 1.00m	K40	GAI	5	*	ST7	SRB
2004 07 21.95	d	C	6.0	LB	6.3	M	8	a180	>10				C12.35m	K40	GAI	5	*	ST7	SRB
2004 07 21.95	d	C	6.1	LB	6.3	M	8	a180	>10				C 7.90m	K40	GAI	5	*	ST7	SRB
2004 07 21.95	d	C	6.3	LB	6.3	M	8	a180	>10				C 3.95m	K40	GAI	5	*	ST7	SRB
2004 07 21.95	d	C	6.7	LB	6.3	M	8	a180	>10				C 2.00m	K40	GAI	5	*	ST7	SRB
2004 07 21.95	d	C	7.3	LB	6.3	M	8	a180	>10				C 1.00m	K40	GAI	5	*	ST7	SRB
2004 08 04.92	d	C	6.0	LB	6.3	M	8	a300	>10				C12.35m	K40	GAI	5	*	ST7	SRB
2004 08 04.92	d	C	6.1	LB	6.3	M	8	a300	>10				C 7.90m	K40	GAI	5	*	ST7	SRB
2004 08 04.92	d	C	6.3	LB	6.3	M	8	a300	>10				C 3.95m	K40	GAI	5	*	ST7	SRB
2004 08 04.92	d	C	6.7	LB	6.3	M	8	a300	>10				C 2.00m	K40	GAI	5	*	ST7	SRB
2004 08 04.92	d	C	7.3	LB	6.3	M	8	a300	>10				C 1.00m	K40	GAI	5	*	ST7	SRB

Φ Φ Φ

ICQ ARCHIVE

With the publication of the July 2005 issue, the *ICQ* archive has now surpassed the 100000 mark in terms of photometric observations of long-period comets; the total stands at 100385 prior to this issue's data, with an additional 54058 observations of short-period comets (including 1-apparition comets). With the help of Maik Meyer, older data are being gradually added to the archive from the literature. The number of requests from researchers for e-mailed archival data continues to rise, as well.

Tabulation of Comet Observations

New CCD data code for CCD camera: `Dil` = DillCam (used on 2.0-m Faulkes Telescope-North), which also uses the new code `EEV` for the 2048×2048 EEV 42-40 chip; the data employing this also use the *IRAF* software to reduce the cometary magnitudes, for which the new software code `IRA` is assigned.

Descriptive Information, to complement the Tabulated Data (all times UT):

See the July 2001 issue (page 98) for explanations of the abbreviations used in the descriptive information.

◇ *Comet 9P/Tempel* ⟹ 2005 July 26.49: *Guide 8.0* software used for comp.-star mags [YOS02]. July 27.46, Sept. 1.45, 8.45, Oct. 1.41, and 20.40: *Guide 8.0* software used for comp.-star mags [TSU02]. July 27.46: comp. star has $B-V$ = +0.61 [TSU02]. Aug. 2.92: alt. 9° [GON05]. Sept. 1.45: comp. star has $B-V = +0.58$ [TSU02]. Sept. 8.45: comp. star has $B-V = +0.57$ [TSU02]. Oct. 1.41: comp. star has $B-V = +0.60$ [TSU02]. Oct. 20.40: comp. star has $B-V = +0.62$ [TSU02].

◇ *Comet 10P/Tempel* ⟹ 2005 Sept. 9.76: *Guide 8.0* software used for comp.-star mags; $B-V$ values of comp. stars are +0.50, +0.51, and +0.57 [OHS].

◇ *Comet 21P/Giacobini-Zinner* ⟹ 2005 July 31.81 and Oct. 1.82: *Guide 8.0* software used for comp.-star mags [TSU02]. July 31.81: comp. star has $B-V = +0.71$ [TSU02]. Aug. 5.77: *StellaNavigator ver. 6* software used for comp.-star mags [NAG08]. Aug. 5.77: *Guide 8.0* software used for comp.-star mags; $B-V$ values of comp. stars are +0.52 and +0.56 [OHS]. Oct. 1.82: comp. star has $B-V = +1.01$ [TSU02].

◇ *Comet 29P/Schwassmann-Wachmann* ⟹ 2005 Aug. 29.66 and Oct. 8.77: *Guide 8.0* software used for comp.-star mags [YOS02]. Aug. 29.66: $B-V$ values of comp. stars are +0.52 and +0.74 [YOS02]. Sept. 9.63: *Guide 8.0* software used for comp.-star mags; $B-V$ values of comp. stars are +0.50, +0.51, and +0.57 [OHS]. Sept. 14.05: strongly condensed; in evolution after the recent outburst [GON05]. Oct. 8.77: $B-V$ values of comp. stars are +0.51 and +0.51 [YOS02]. Oct. 24.61: "unexpectedly, I could see an extremely diffuse, large object at the" predicted position [YOS04].

◇ *Comet 37P/Forbes* ⟹ 2005 July 26.52 and Aug. 10.55: *Guide 8.0* software used for comp.-star mags [YOS02]. Aug. 2.94: alt. 8° [GON05]. Aug. 3.50, Sept. 1.53, 8.48, 23.45, and Oct. 19.44: *Guide 8.0* software used for comp.-star mags [TSU02]. Aug. 3.50: comp. star has $B-V = +0.70$ [TSU02]. Aug. 10.55: comp. star has $B-V = +0.73$ [YOS02]. Sept. 1.53: comp. star has $B-V = +0.62$ [TSU02]. Sept. 8.46: faint, diffuse object near the Lagoon Nebula; background filled with many faint stars, and a star of mag 13.5 overlapping coma [YOS04]. Sept. 8.48: comp. star has $B-V = +0.65$ [TSU02]. Sept. 23.45: comp. star has $B-V = +0.54$ [TSU02]. Oct. 19.44: comp. star has $B-V = +0.57$ [TSU02].

◇ *Comet 65P/Gunn* ⟹ 2005 Sept. 9.78: *Guide 8.0* software used for comp.-star mags; $B-V$ values of comp. stars are +0.50, +0.51, and +0.57 [OHS].

◇ *Comet 74P/Smirnova-Chernykh* ⟹ 2005 Sept. 9.68: *Guide 8.0* software used for comp.-star mags; $B-V$ values of comp. stars are +0.50, +0.51, and +0.57 [OHS].

◇ *Comet 101P/Chernykh* ⟹ 2005 Aug. 5.71 and Sept. 9.74: *Guide 8.0* software used for comp.-star mags [OHS]. Aug. 5.71: comp. star has $B-V = +0.56$ [OHS]. Sept. 1.60, 30.63, and Oct. 1.63: *Guide 8.0* software used for comp.-star mags [TSU02]. Sept. 1.60: comp. star has $B-V = +0.33$ [TSU02]. Sept. 9.74: $B-V$ values of comp. stars are +0.50, +0.51, and +0.57 [OHS]. Sept. 30.63: comp. star has $B-V = +0.40$ [TSU02]. Oct. 1.63: comp. star has $B-V = +0.59$ [TSU02].

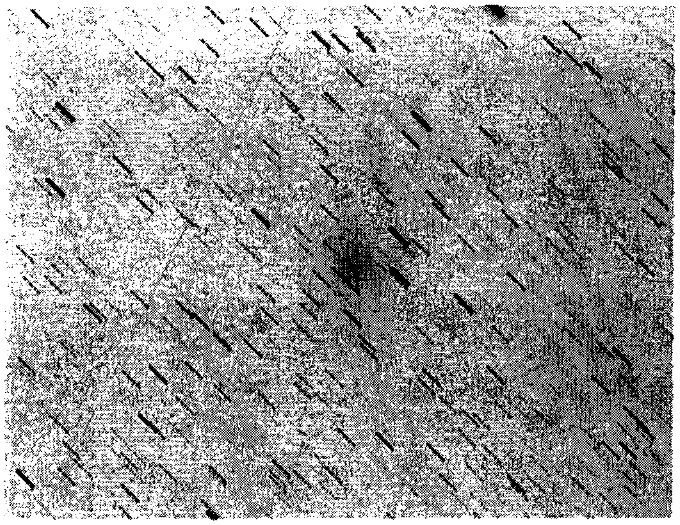
◇ *Comet 107P/Wilson-Harrington* ⟹ 2005 July 31.80 and Sept. 8.81: *Guide 8.0* software used for comp.-star mags [TSU02]. July 31.80: comp. star has $B-V = +0.72$ [TSU02]. Sept. 8.81: comp. star has $B-V = +0.24$ [TSU02].

◇ *Comet 117P/Helin-Roman-Alu* ⟹ 2005 Aug. 3.48: *Guide 8.0* software used for comp.-star mags; comp. star has $B-V = +0.50$ [TSU02].

◇ *Comet 161P/Hartley-IRAS* ⟹ 2005 July 26.55: *Guide 8.0* software used for comp.-star mags [YOS02]. July 27.50, Aug. 3.56, 27.44, Sept. 1.47, and 9.46: *Guide 8.0* software used for comp.-star mags [TSU02]. July 27.50: comp. star has $B-V = +0.73$ [TSU02]. Aug. 2.93: some interference from nearby star of magn 12.3 (ref = TA) [BOU]. Aug. 3.56: comp. star has $B-V = +0.61$ [TSU02]. Aug. 16.89: 88%-illuminated moon at alt. 8° behind buildings; good transparancy [GIL01]. Aug. 27.44: comp. star has $B-V = +0.39$ [TSU02]. Aug. 31.47: *Guide 6* software used for comp.-star mags [NAG08]. Sept. 1.47: comp. star has $B-V = +0.55$ [TSU02]. Sept. 9.46: comp. star has $B-V = +0.44$ [TSU02].

◇ *Comet 168P/Hergenrother* ⟹ 2005 Sept. 8.60, 30.51, Oct. 1.51, and 19.46: *Guide 8.0* software used for comp.-star mags [TSU02]. Sept. 8.60: comp. star has $B-V = +0.53$ [TSU02]. Sept. 25.56: *Guide 8.0* software used for comp.-star mags; $B-V$ values of comp. stars are +0.63 and +0.70 [YOS02]. Sept. 30.51: comp. star has $B-V = +0.65$ [TSU02]. Oct. 1.51 and 19.46: comp. star has $B-V = +0.33$ [TSU02].

◇ *Comet 169P/2002 EX_{12} (NEAT)* ⟹ 2005 Aug. 2.95: faint stellar object; motion near star of mag 12.8 (HS) obvious over a 10-min period; comp. stars used from Henden photometry near Z UMi; (general note) all positions of



CCD image of comet 169P taken by M. Jäger a 20-cm f/1.5 Schmidt telescope on 2005 Aug. 12.87 UT, when the comet was around mag 12.5 with a coma diameter of 4′-5′ (it was about 15°-20° above the evening horizon).

◇ ◇ ◇

[text continued from page 263]

comets fainter than mag 13.5 (including also obs. in this issue for C/2005 K1 and P/2005 K3) were checked against the Digitized Sky Survey (DSS) to avoid confusion with faint stars or nearby galaxies; positions of comets were calculated using most recent orbital elements from *MPECs* or CBAT/MPC/ICQ website; for comets > 3 months from perihelion, orbital elements for epoch 2005 July 29 or Aug. 18 were calculated from positions published in *MPECs* (using Bill Gray's `FIND_ORB` [BOU and DIJ]. Sept. 11.80: $B-V$ values of comp. stars are +0.62 and +0.72; almost-stellar central cond.; narrow, straight tail [KAD02]. Sept. 12.79: $B-V$ values of comp. stars are +0.75 and 0.55; strong central cond.; narrow, straight tail [KAD02]. Sept. 14.19: mountain location, very clear sky; alt. 12° [GON05]. Oct. 7.20: mountain location, very clear sky; zodiacal light; alt. 17°; comet close to star of mag 12.2 (ref = HS) [GON05]. Oct. 8.83: *Guide 8.0* software used for comp.-star mags; $B-V$ values of comp. stars are +0.51 and +0.51 [YOS02].

◇ *Comet 170P/2005 M1 (Christensen)* ⟹ 2005 Sept. 8.63: *Guide 8.0* software used for comp.-star mags; comp. star has $B-V = +0.77$ [TSU02]. Sept. 9.66: *Guide 8.0* software used for comp.-star mags; $B-V$ values of comp. stars are +0.50, +0.51, and +0.57 [OHS].

◇ *Comet 171P/Spahr* ⟹ 2005 Oct. 1.80: *Guide 8.0* software used for comp.-star mags; comp. star has $B-V = +0.53$ [TSU02].

◇ *Comet C/2002 VQ*$_{94}$ *(LINEAR)* ⟹ 2005 Sept. 12.76: *Guide 8.0* software used for comp.-star mags; comp. star has $B-V = +0.65$ [OHS].

◇ *Comet C/2003 K4 (LINEAR)* ⟹ 2005 Sept. 8.79 and Oct. 1.74: *Guide 8.0* software used for comp.-star mags [TSU02]. Sept. 8.79: comp. star has $B-V = +0.67$ [TSU02]. Oct. 1.74: comp. star has $B-V = +0.60$ [TSU02]. Oct. 8.81: *Guide 8.0* software used for comp.-star mags; $B-V$ values of comp. stars are +0.51 and +0.51 [YOS02]. Oct. 12.73: *Guide 8.0* software used for comp.-star mags; $B-V$ values of comp. stars are +0.50, +0.55, and +0.83 [OHS]. Oct. 24.63: w/ 0.40-m *f*/4.5 reflector, easy to see under the moonlight; moderately condensed [YOS04].

◇ *Comet C/2003 T4 (LINEAR)* ⟹ 2005 Oct. 1.84: *Guide 8.0* software used for comp.-star mags; comp. star has $B-V = +0.43$ [TSU02].

◇ *Comet C/2003 WT*$_{42}$ *(LINEAR)* ⟹ 2005 Oct. 12.75: *Guide 8.0* software used for comp.-star mags; $B-V$ values of comp. stars are +0.50, +0.55, and +0.83 [OHS]. Oct. 24.79: "hard to see due to moonlight, but I could see a small, moderately condensed comet; I could not see a 15th-mag star near by the comet; I could not confirm it on the next night because of clouds" [YOS04].

◇ *Comet C/2004 D1 (NEAT)* ⟹ 2005 Sept. 12.77: *Guide 8.0* software used for comp.-star mags; comp. star has $B-V = +0.65$ [OHS].

◇ *Comet P/2004 F3 (NEAT)* ⟹ 2005 July 31.61 and Sept. 9.48: *Guide 8.0* software used for comp.-star mags [TSU02]. July 31.61: comp. star has $B-V = +0.55$ [TSU02]. Aug. 10.60: *Guide 8.0* software used for comp.-star mags; $B-V$ values of comp. stars are +0.69 and +0.73 [YOS02]. Sept. 9.48: comp. star has $B-V = +0.59$ [TSU02].

◇ *Comet P/2004 FY*$_{140}$ *(LINEAR)* ⟹ 2001, 2002, and 2003: "There are eight pairs or triplets of NEAT images that show the field of 2004 FY$_{140}$ at various dates in these three years, but none of these show any trace of the object's presence; the four sets of images from 2001-2002 (when the object was predicted to be at mag $V \sim 19.6$) were examined out to nominal $\pm 3\sigma$ uncertainty (limiting magnitude was $R \sim 20$); the four sets from 2002-2003 (when the object was predicted to be at $V \sim 18.7$, and the R.A. uncertainty about half that of 2001-2002) were examined out to nominal $\pm 6\sigma$ uncertainty (again, limiting magnitude $R \sim 20$) — a moving object of $V = 18.7$ ($R \sim 18.3$) would have stood out like a sore thumb, so either this object was anomalously bright in 2004, or the orbit is more uncertain than it appears to be" [Gareth V. Williams, Minor Planet Center]. 2004 May 19 and 20: "R-band obs. show the object to be cometary; no tail was detected, but the object was consistently non-stellar on individual and co-added frames" [Carl W. Hergenrother, Catalina 1.54-m reflector near Tucson, AZ]. 2005 July 5 and 6: "attempts to image the comet with the Catalina 1.54-m reflector failed, even though the object was predicted to be at $V \sim 19$ at the time (no object was detected down to $V \sim 22$; an area covering 15$'$ of the line-of-variation was covered; this non-detection suggests that it has not followed a typical asteroidal brightening law; the orbit is a little uncertain but it should have been located in my field-of-view" [Hergenrother].

◇ *Comet C/2004 Q2 (Machholz)* ⟹ 2005 July 26.53, Aug. 10.52, Sept. 25.45: *Guide 8.0* software used for comp.-star mags [YOS02]. July 27.52, Aug. 4.48, Sept. 1.48, 9.43, 25.43, Oct. 1.43, and 19.39: *Guide 8.0* software used for comp.-star mags [TSU02]. July 27.52: comp. star has $B-V = +0.49$ [TSU02]. Aug. 4.48: comp. star has $B-V = +0.57$ [TSU02]. Aug. 10.52: $B-V$ values of comp. stars are +0.50 and +0.67 [YOS02]. Sept. 1.48: comp. star has $B-V = +0.43$ [TSU02]. Sept. 9.43: comp. star has $B-V = +0.55$ [TSU02]. Sept. 25.45: $B-V$ values of comp. stars are +0.73 and +0.76 [YOS02]. Sept. 25.43: comp. star has $B-V = +0.76$ [TSU02]. Oct. 1.43: comp. star has $B-V = +0.85$ [TSU02]. Oct. 19.39: comp. star has $B-V = +0.48$ [TSU02].

◇ *Comet C/2005 A1 (LINEAR)* ⟹ 2005 Aug. 5.67: *Guide 8.0* software used for comp.-star mags; $B-V$ values of comp. stars are +0.52 and +0.56 [OHS]. Aug. 5.76: *StellaNavigator ver. 6* software used for comp.-star mags [NAG08]. Aug. 29.59 and Sept. 25.59: *Guide 8.0* software used for comp.-star mags [YOS02]. Aug. 29.59: $B-V$ values of comp. stars are +0.50 and +0.67 [YOS02]. Sept. 1.57, 3.66, 8.67, 30.60, Oct. 1.57, 19.58, and 20.58: *Guide 8.0* software used for comp.-star mags [TSU02]. Sept. 1.57: comp. star has $B-V = +0.44$ [TSU02]. Sept. 4.86: fragment B not found; interference from nearby star of mag 15.1 [HAS02]. Sept. 8.67: comp. star has $B-V = +0.80$ [TSU02]. Sept. 25.59: $B-V$ values of comp. stars are +0.70 and +0.70 [YOS02]. Sept. 30.60: comp. star has $B-V = +0.40$ [TSU02]. Oct. 1.57: comp. star has $B-V = +0.50$ [TSU02]. Oct. 19.58 and 20.58: comp. star has $B-V = +0.41$ [TSU02].

◇ *Comet C/2005 E2 (McNaught)* ⟹ 2005 July 31.64, Sept. 9.50, 30.46, and Oct. 20.44: *Guide 8.0* software used for comp.-star mags [TSU02]. July 31.64: comp. star has $B-V = +0.41$ [TSU02]. Aug. 2.42: comet involved with faint stars [SEA]. Aug. 3.00: mountain location, very clear sky; alt. 7° [GON05]. Aug. 10.59 and Sept. 25.5: *Guide 8.0* software used for comp.-star mags [YOS02]. Aug. 10.59: $B-V$ values of comp. stars are +0.69 and +0.73 [YOS02]. Aug. 28.89: mountain location, clear sky; alt. 8° [GON05]. Sept. 2.90 and 8.89: alt. 9° [GON05]. Sept. 7.92: alt. 8° [GON05]. Sept. 8.47: small and very strongly condensed; easy object in a clear sky despite the low alt. [YOS04]. Sept. 9.50: comp. star has $B-V = +0.75$ [TSU02]. Sept. 21.83: alt. 11° [GON05]. Sept. 25.44: *StellaNavigator* ver. 6.1 software used for comp.-star mags [NAG08]. Sept. 25.51: comp. star has $B-V = +0.60$ [YOS02]. Sept. 25.84: alt. 12° [GON05]. Sept. 30.46: comp. star has $B-V = +0.73$ [TSU02]. Oct. 20.44: comp. star has $B-V = +0.48$ [TSU02]. Oct. 24.40: central cond. not as sharp as before; easy to see [YOS04]. Oct. 26.84: alt. 11° [GON05].

◇ *Comet P/2005 JQ_5 (Catalina)* ⟹ 2005 May 17.5: seven co-added 40-sec R-band exposures, taken as on June 9.38 (see below) show a coma elongated at p.a. 140° and extending to 10$''$ from the nuclear cond. (but no tail visible) [FIT02, Stephen Lowry, and Colin Snodgrass, Queen's University, Belfast, N. Ireland]. June 9.38: 2.0-m Faulkes Telescope-North used; photometric conditions, "so we did a standard calibration for zero points, extinction coefficients, and color terms"; CCD camera binned at 2×2; three co-added 10-sec R-band exposures show the coma elongated in p.a. 130°, extending up to 9$''$ from the nuclear cond. — this merging into a faint tail ≈ 35$''$ long (as measured from the nuclear cond.) in p.a. 130° [FIT02]. Aug. 5.76: *Guide 8.0* software used for comp.-star mags; $B-V$ values of comp. stars are +0.52 and +0.56 [OHS].

◇ *Comet C/2005 K1 (Skiff)* ⟹ 2005 July 31.55, Aug. 27.55, Sept. 1.54, Oct. 1.48, and 19.40: *Guide 8.0* software used for comp.-star mags [TSU02]. July 31.55: comp. star has $B-V = +0.41$ [TSU02]. Aug. 2.98: faint, diffuse object; DSS shows nothing near obs. position; some interference from nearby star of mag 10.6 (ref = TK); comp. stars taken from Henden photometry near Z UMi (see also comments for comet 169P, above) [BOU and DIJ]. Aug. 10.57: *Guide 8.0* software used for comp.-star mags; $B-V$ values of comp. stars are +0.56 and +0.72 [YOS02]. Aug. 27.55: comp. star has $B-V = +0.84$ [TSU02]. Aug. 28.87: ephemeris from MPC Ephemeris service; checked Digitized Sky Survey (limiting stellar mag 15.5) [HAS02]. Sept. 1.54: comp. star has $B-V = +0.53$ [TSU02]. Sept. 1.84, 5.84, 6.84, and 7.88: limiting mag ~ 16 at 81× [LEH]. Sept. 1.84: second confirming detection at Sept. 1.93 [LEH]. Sept. 5.84: second confirming detection at Sept. 5.93 [LEH]. Sept. 6.84: second confirming detection at Sept. 6.93 [LEH]. Sept. 7.88: no second confirming detection (low alt.) [LEH]. Sept. 9.53: *Guide 8.0* software used for comp.-star mags; $B-V$ values of comp. stars are +0.50, +0.51, and +0.57 [OHS]. Oct. 1.48: comp. star has $B-V = +0.72$ [TSU02]. Oct. 19.40: comp. star has $B-V = +0.64$ [TSU02].

◇ *Comet P/2005 K3 (McNaught)* ⟹ 2005 Aug. 29.65: *Guide 8.0* software used for comp.-star mags; $B-V$ values of comp. stars are +0.40 and +0.53 [YOS02]. Aug. 29.99: ephemeris from MPC Ephemeris service; checked Digitized Sky Survey (limiting stellar mag 15.5) [HAS02]. Sept. 3.96: small, condensed object; motion obvious over a 30-min period (see also comments for comet 169P above) [BOU]. Oct. 1.77: *Guide 8.0* software used for comp.-star mags; comp. star has $B-V = +0.46$ [TSU02]. Oct. 12.71: *Guide 8.0* software used for comp.-star mags; $B-V$ values of comp. stars are +0.50, +0.55, and +0.83 [OHS]. Oct. 24.65: "very near the half moon; many faint stars in field, so it was hard to confirm a diffuse faint comet" [YOS04].

◇ *Comet C/2005 L3 (McNaught)* ⟹ 2005 Sept. 8.55: *Guide 8.0* software used for comp.-star mags; comp. star has $B-V = +0.53$ [TSU02].

◇ *Comet C/2005 N1 (Juels-Holvorcem)* ⟹ 2005 July 31.76: *Guide 8.0* software used for comp.-star mags; comp. star has $B-V = +0.43$ [TSU02]. Aug. 5.75: *Guide 8.0* software used for comp.-star mags; $B-V$ values of comp. stars are +0.52 and +0.56 [OHS]. Sept. 8.85: alt. 6° [GON05]. Sept. 11.81: *Guide 8.0* software used for comp.-star mags [YOS02]. Sept. 14.18: alt. 13° [GON05]. Sept. 30.20: mountain location, very clear sky; alt. 13°; some moonlight interference [GON05]. Oct. 7.21: obs. at beginning of morning astron. twilight; alt. 16° [GON05].

◇ *Comet P/2005 N3 (Larson)* ⟹ 2005 Sept. 8.57: *Guide 8.0* software used for comp.-star mags; comp. star has $B-V = +0.92$ [TSU02].

◇ *Comet C/2005 N5 (Catalina)* ⟹ 2005 Aug. 5.73: *Guide 8.0* software used for comp.-star mags; comp. star has $B-V = +0.56$ [OHS]. Sept. 8.72 and Oct. 1.63: *Guide 8.0* software used for comp.-star mags [TSU02]. Sept. 8.72: comp. star has $B-V = +0.62$ [TSU02]. Oct. 1.63: comp. star has $B-V = +0.93$ [TSU02].

◇ *Comet C/2005 P3 (SWAN)* ⟹ 2005 Aug. 27.43 and Sept. 8.42: *Guide 8.0* software used for comp.-star mags [TSU02]. Aug. 27.43: comp. star has $B-V = +0.39$ [TSU02]. Aug. 28.86: comet close to star of mag 10.7 (ref TK) [BOU]. Aug. 28.86: mountain location, clear sky; alt. 15°; slightly enhanced through Swan Band filter [GON05]. Aug. 29.45 and 31.45: *MegaStar* ver. 5.0 software used for comp.-star mags [MUR02]. Aug. 29.9: mountain location, clear sky; alt. 13° [GON05]. Sept. 7.86 and 8.87: mountain location, clear sky; alt. 14° [GON05]. Sept. 8.42: comp. star has $B-V = +0.55$ [TSU02]. Sept. 8.44: "very large; diffuse but clearly visible; impressive view despite the low alt.; due to the diffuse surface, it looks fainter with higher magnification" [YOS04]. Sept. 12.79: *Guide 8.0* software used for comp.-star mags; $B-V$ values of comp. stars are +0.53 and +0.70 [OHS]. Sept. 14.17: mountain location, very clear sky; alt. 16° [GON05]. Oct. 24.78: surprised to see that comet was still visible; extremely diffuse and faint [YOS04].

◇ *Comet P/2005 R1 (NEAT)* ⟹ 2005 Sept. 9.53: *Guide 8.0* software used for comp.-star mags; $B-V$ values of comp. stars are +0.50, +0.51, and +0.57 [OHS]. Oct. 1.74: *Guide 8.0* software used for comp.-star mags; comp. star has $B-V = +0.49$ [TSU02].

◇ *Comet P/2005 R2 (Van Ness)* ⟹ 2005 Sept. 12.65: *Guide 8.0* software used for comp.-star mags; $B-V$ values of comp. stars are +0.53 and +0.70 [OHS]. Sept. 25.85: ephemeris from MPC Ephemeris service; checked Digitized Sky Survey (limiting stellar mag 15.5) [HAS02]. Oct. 7.18: obs. from Alto del Castro-Aralla at elev. 1720 m, near Leon in northern Spain [GON05]. Oct. 8.76: *Guide 8.0* software used for comp.-star mags; $B-V$ values of comp. stars are +0.51 and +0.51 [YOS02]. Oct. 24.60: moderately condensed and clearly visible overhead [YOS04].

◇ *Comet C/2005 T4 (SWAN)* ⟹ 2005 Oct. 23.38: *Guide 8.0* software used for comp.-star mags; comp. star has $B-V = +0.64$ [TSU02]. Oct. 24.39: new comet just discovered; very low in the evening, diffuse; position consistent with John Drummond's obs. posted to `comets-ml` e-mail discussion group [YOS04]. Oct. 26.80: alt. 8° [GON05].

◇ ◇ ◇

Key to observers with observations published in this issue, *with 2-digit numbers between Observer Code and Observer's Name indicating source [16 = Japanese observers (via Akimasa Nakamura, Kuma, Ehime); 32 = Hungarian observers (via Krisztián Sárneczky, Budapest); etc.]:*

BOU		Reinder J. Bouma, The Netherlands
DID01	37	Kostiantyn Didiborets, Ukraine
DIJ		Edwin van Dijk, The Netherlands
DUB01	37	Yuriy Dubrovsky, Kyiv, Ukraine
FIT02		Alan Fitzsimmons, Belfast, U.K.
GIL01		Guus Gilein, The Netherlands
GON05		Juan J. Gonzalez, Asturias, Spain
HAS02		Werner Hasubick, Germany
HOR02	23	Kamil Hornoch, Czech Republic
KAD02	16	Ken-ichi Kadota, Saitama, Japan
LAB02		Carlos Labordena, Castellon, Spain
LEH		Martin Lehky, Czech Republic
MAR02	13	Jose Carvajal Martinez, Spain
MIY01	16	Osamu Miyazaki, Ibaraki, Japan
MUR02	16	Shigeki Murakami, Niigata, Japan
NAG08	16	Yoshimi Nagai, Gunma, Japan
NEV	42	Vitali S. Nevski, Vitebsk, Belarus
OHS	16	Yuuji Ohshima, Nagano, Japan
PER01		Alfredo J. S. Pereira, Portugal
PIL01		Uwe Pilz, Leipzig, Germany
SAN04	38	Juan M. San Juan, Madrid, Spain
SAN07	32	Gábor Sánta, Kisujszállás, Hungary
SAR02	32	K. Sárneczky, Budapest, Hungary
SEA		David A. J. Seargent, Australia
SHU	42	Sergey E. Shurpakov, Belarus
SRB	23	Jiri Srba, Vsetin, Czech Republic
SZA		Sándor Szabó, Sopron, Hungary
TOT03	32	Zoltán Tóth, Hungary
TSU02	16	Mitsunori Tsumura, Wakayama, Japan
URB01	23	Ľubomír Urbančok, Slovak Republic
YOS02	16	Katsumi Yoshimoto, Hirao, Japan
YOS04	16	Seiichi Yoshida, Japan

Visual Data

TABULATED VISUAL DATA (also format for old-style CCD data)

NOTE: As begun in the October 2001 issue, the CCD and visual tabulated data are separated. The tabulated CCD data are also now generally further separated into two "CCD" sections: the first in the old format for those observations submitted only in the old format, and the second in the new format (whose columns are described on page 208 of the July 2002 *ICQ*).

The headings for the tabulated data are as follows: "DATE (UT)" = Date and time to hundredths of a day in Universal Time; "N" = notes [`*` = correction to observation published in earlier issue of the *ICQ*; an exclamation mark (`!`) in this same location indicates that the observer has corrected his estimate in some manner for atmospheric extinction (prior to September 1992, this was the standard symbol for noting extinction correction, but following publication of the extinction paper — July 1992 *ICQ* — this symbol is only to be used to denote corrections made using procedures different from that outlined by Green 1992, *ICQ* **14**, 55-59, and in Appendix E of the *ICQ Guide to Observing Comets* — and then only for situations where the observed comet is at altitude > 10°); '`&`' = comet observed at altitude 20° or less with no atmospheric extinction correction applied; '`$`' = comet observed at altitude 10° or lower, observations corrected by the observer using procedure of Green (*ibid.*); for a correction applied by the observer using Tables Ia, Ib, or Ic of Green (*ibid.*), the letters '`a`', '`w`', or '`s`', respectively, should be used; `x` indicates that a secondary source (often amateur computer software) was used to get supposedly correct comparison-star magnitudes from an accepted catalogue].

"MM" = the method employed for estimating the total (visual) magnitude; see article on page 186 of the Oct. 1996 issue [B = VBM method, M = Morris method, S = VSS or In-Out method, I = in-focus, C = unfiltered CCD, c = same as 'C', but for 'nuclear' magnitudes, V = electronic observations — usually CCD — with Johnson V filter, *etc.*]. "MAG." = total (visual) magnitude estimate; a colon indicates that the observation is only approximate, due to bad weather conditions, *etc.*; a left bracket ([) indicates that the comet was not seen, with an estimated limiting magnitude given (if the comet IS seen, and it is simply estimated to be fainter than a certain magnitude, a "greater-than" sign (>) must be used, not a bracket). "RF" = reference for total magnitude estimates (see pages 98-100 of the October 1992 issue, and Appendix C of the *ICQ Guide to Observing Comets*, for all of the 1- and 2-letter codes; an updated list is also maintained at the *ICQ* World Wide Website). "AP." = aperture in centimeters of the instrument used for the observations, usually given to tenths. "T" = type of instrument used for the observation (R = refractor, L = Newtonian reflector, B = binoculars, C = Cassegrain reflector, A = camera, T = Schmidt-Cassegrain reflector, S = Schmidt-Newtonian reflector, E = naked eye, *etc.*). "F/" and "PWR" are the focal ratio and power or magnification, respectively, of the instrument used for the observation — given to nearest whole integer (round even); note that for CCD observations, in place of magnification is given the exposure time in seconds [see page 11 of the January 1997 issue; a lower-case "`a`" indicates an exposure time under 1000 seconds, an upper-case "`A`" indicates an exposure time of 1000-1999 seconds (with the thousands digit replaced by the "`A`"), an upper-case "`B`" indicates an exposure time of 2000-2999 seconds (with the thousands digit replaced by the "`B`"), etc.].

"COMA" = estimated coma diameter in minutes of arc; an ampersand (&) indicates an approximate estimate; an exclamation mark (!) precedes a coma diameter when the comet was not seen (*i.e.*, was too faint) and where a limiting magnitude estimate is provided based on an "assumed" coma diameter (a default size of 1′ or 30″ is recommended; cf. *ICQ* **9**, 100); a plus mark (+) precedes a coma diameter when a diaphragm was used electronically, thereby specifying the diaphragm size (i.e., the coma is almost always larger than such a specified diaphragm size). "DC" = degree of condensation on a scale where 9 = stellar and 0 = diffuse (preceded by lower- and upper-case letters S and D to indicate the presence of stellar and disklike central condensations; cf. July 1995 issue, p. 90); a slash (/) indicates a value midway between the given number and the next-higher integer. "TAIL" = estimated tail length in degrees, to 0.01 degree if appropriate; again, an ampersand indicates a rough estimate. Lower-case letters between the tail length and the p.a. indicate that the tail was measured in arcmin ("m") or arcsec ("s"), *in which cases the decimal point is shifted one column to the right.* "PA" = estimated measured position angle of the tail to nearest whole integer in degrees (north = 0°, east = 90°). "OBS" = the observer who made the observation (given as a 3-letter, 2-digit code).

A complete list of the Keys to abbrevations used in the *ICQ* is available from the Editor for $4.00 postpaid (available free of charge via e-mail); these Keys (with the exception of the Observer Codes) are also available in the *Guide to Observing Comets* and via the *ICQ*'s World Wide Web site. *Please note that data in archival form, and thus the data to be sent in machine-readable form, use a format that is different from that of the Tabulated data in the printed pages of the ICQ;* see pages 59-61 of the July 1992 issue, p. 10 of the January 1995 issue, and p. 100 of the April 1996 issue for further information [note correction on page 140 of the October 1993 issue]. Further guidelines concerning reporting of data may be found on pages 59-60 of the April 1993 issue, and in the *ICQ Guide to Observing Comets*.

◇ ◇ ◇

NOTE: *The new-style CCD tabulated data begin on page 275 of this issue.*

◇ ◇ ◇

Comet 9P/Tempel

DATE (UT)	N	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
2005 06 27.88		M	9.7	TT	10	B	4	25	6	3			LEH
2005 06 28.88		M	9.6	TT	10	B	4	25	7	3			LEH
2005 07 03.88		M	9.9	TT	20	L	4	42	5	3/			LEH
2005 07 03.88		S	10.8	HS	27.0	L	6	83	3	2/			TOT03
2005 07 06.88		M	9.0	TT	10	B	4	25	5	5			LEH
2005 07 06.88		S	10.0	HS	11.4	L	5	50	3.5	1/			SAN07
2005 07 26.49		S	12.1	AU	25.4	L	4	113	1.4	5			YOS02
2005 07 29.44		S	11.0	GA	25.4	L	4	71	4				SEA
2005 08 01.43		S	11.0	GA	25.4	L	4	71	4				SEA
2005 08 02.92		S	10.9	TK	20.3	T	10	100	2.5	3			GON05
2005 08 05.47		S	10.9	TJ	40.0	L	4	144	1.5	3			YOS04
2005 08 05.92		S	10.9	NP	32	L	5	75	4	2/			MAR02
2005 08 06.86		S	12.1	TI	23.5	T	10	94	2	2			LAB02
2005 09 03.86		S	11.7	TI	44.5	L	5	65	2	1/			MAR02

Comet 21P/Giacobini-Zinner

DATE (UT)	N	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
2005 08 02.14		S	10.4	TK	20.3	T	10	100	3	4			GON05
2005 08 05.77		S	10.4	TJ	40.0	L	4	144	2.3	3/			YOS04
2005 08 05.77	x	S	10.8	TJ	32.0	L	5	87	1.6	4			NAG08
2005 08 06.78		S	[9.5	TJ	40.0	L	4	144	! 2.0				YOS04
2005 08 07.14		S	10.6	TI	23.5	T	10	94	3	2			LAB02
2005 10 24.80		S	[12.5	AU	40.0	L	4	144	! 0.8				YOS04

Comet 29P/Schwassmann-Wachmann

DATE (UT)	N	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
2005 07 04.02		S	[12.5	HS	40.5	L	4	128	! 1.0				SAR02
2005 07 15.04		S	11.6	TK	15	L	6	61	1.1	6/			URB01
2005 07 16.02		S	11.7	TK	15	L	6	61	1	6			URB01
2005 08 04.73		S	[12.4	AU	40.0	L	4	144	! 0.8				YOS04
2005 08 05.70		S	[12.8	AU	40.0	L	4	144	! 0.7				YOS04
2005 08 06.77		S	[12.9	AU	40.0	L	4	144	! 0.7				YOS04
2005 09 10.86		S	13.2	HS	30	L	5	180	0.5	4			NEV
2005 09 14.03		M	13.5	GA	41	L	4	113	1	3			SHU
2005 09 14.05		B	13.5	AU	20.3	T	10	133	0.3	7			GON05
2005 10 01.94		S	14.0	NP	44.5	L	5	100	0.75	1			MAR02
2005 10 24.61		S	12.8	AU	40.0	L	4	144	1.2	1			YOS04

Comet 32P/Comas Solá

DATE (UT)	N	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
2004 11 16.66	x	S	13.4	HS	31.7	L	6	152	0.9	3			MIY01

Comet 37P/Forbes

DATE (UT)	N	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
2005 07 26.52		S	12.0:	AU	25.4	L	4	113	1.0	4			YOS02
2005 07 29.53		S	12.6	GA	25.4	L	4	71					SEA
2005 08 02.94		S	12.2	TK	20.3	T	10	160	0.8	3			GON05
2005 08 03.89		S	10.8	NP	25.5	L	5	60	1.5	2			MAR02
2005 08 04.89		S	10.7	NP	25.5	L	5	60	2	2			MAR02
2005 08 05.48		S	[10.7	AU	40.0	L	4	144	! 1.4				YOS04
2005 08 05.91		S	10.6	NP	32	L	5	75	2	2			MAR02
2005 08 06.87		S	11.7	TI	23.5	T	10	94	2	2			LAB02
2005 09 08.46		S	13.0	AU	40.0	L	4	144	1.1	3			YOS04

Comet 101P/Chernykh

DATE (UT)	N	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
2005 08 31.00		B	14.1	HS	42	L	5	81	1	4			LEH
2005 09 06.00		B	14.1	HS	42	L	5	81	0.9	4			LEH
2005 09 07.00		B	14.2	HS	42	L	5	81	0.9	4			LEH
2005 09 30.90		S	[13.2	HS	27.0	L	6	83	! 1.0				TOT03

Comet 101P/Chernykh [cont.]

DATE (UT)	N	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
2005 10 24.62		S	13.5	AU	40.0	L	4	144	1.2	4			YOS04

Comet 161P/Hartley-IRAS

DATE (UT)	N	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
2005 07 03.91		S	10.8	TK	10	B		25	3.1	3/			URB01
2005 07 03.96		S	11.3	HS	27.0	L	6	83	2.5	2			TOT03
2005 07 04.01		S	11.5	HS	40.5	L	4	128	2	3			SAR02
2005 07 06.98		S	10.5	HS	11.4	L	5	50	3	2			SAN07
2005 07 07.92		S	10.5	HS	11.4	L	5	50	2.5	1			SAN07
2005 07 07.94		S	10.7	TK	10	B		25	3.3	3/			URB01
2005 07 14.98		S	10.9	TK	15	L	6	61	3.8	2			URB01
2005 07 15.96		S	10.5	HS	11.4	L	5	50	3	0/			SAN07
2005 07 15.98		S	10.9	TK	15	L	6	45	5.2	2			URB01
2005 07 26.55	x	S	11.0	TK	25.4	L	4	46	2.5	2			YOS02
2005 07 27.92		S	11.2	TK	13	L	8	55	3.8	2			URB01
2005 07 28.92		S	11.3	TK	13	L	8	55	3.4	3			URB01
2005 07 29.93		S	11.3	TK	13	L	8	55	3.8	3			URB01
2005 07 30.92		S	11.5	TK	13	L	8	55	4.0	3			URB01
2005 08 02.89		S	11.2	TK	30	L	5	60	2.5	1			NEV
2005 08 02.93		S	11.6	TA	31.0	J	6	89	1.8	3			DIJ
2005 08 02.93		S	11.8	TA	31.0	J	6	89	1.8	2/			BOU
2005 08 02.98		S	11.6	TK	20.3	T	10	100	2	3			GON05
2005 08 03.97		M	10.7	NP	25.5	L	5	60	3.5	3			MAR02
2005 08 05.51		S	11.4	TJ	40.0	L	4	144	1.6	4			YOS04
2005 08 05.96		S	11.7	TA	31.0	J	6	89	2	3			BOU
2005 08 05.98		M	11.0	NP	32	L	5	75	2.5	3			MAR02
2005 08 06.90		S	11.4	TK	13	L	8	55	3.1	2			URB01
2005 08 06.90		S	11.7	TI	23.5	T	10	57	3	2			LAB02
2005 08 06.92		S	11.4	HS	35.0	L	5	100	3	2			SZA
2005 08 12.84		S	11.7	TK	30	L	5	60	2.5	2			NEV
2005 08 15.86		S	12.2	HS	30	L	5	60	2	2			NEV
2005 08 16.89		S	11.6:	TK	30.5	L	5	180	1.5	4			GIL01
2005 08 28.87		S	11.7	TK	44.0	L	5	63	1.5	2			HAS02
2005 08 28.88		S	12.2	TA	25.4	J	6	88	2.3	1/			BOU
2005 08 28.88		S	12.3	TA	30.5	L	5	180	1.0	2			GIL01
2005 08 30.80		M	11.7	TI	42	L	5	66	2.7	3			LEH
2005 08 31.47	x	S	[12.5	HS	32.0	L	5	87	! 1.4				NAG08
2005 09 01.80		M	11.8	HS	42	L	5	66	2.5	3			LEH
2005 09 03.88		S	12.6	TA	31.0	J	6	89	2.2	2			BOU
2005 09 03.89		S	12.6	TA	31.0	J	6	89	1.5	1/			DIJ
2005 09 03.90		S	12.9	NP	44.5	L	5	100	1.5	1			MAR02
2005 09 04.83		S	12.6	HS	32.0	L		72	1.8				PIL01
2005 09 05.80		M	12.1	HS	42	L	5	66	2.5	3			LEH
2005 09 06.80		M	12.1	HS	42	L	5	66	2.5	3			LEH
2005 09 06.85		M	12.4	HS	35	L	5	68	3	3			HOR02
2005 09 07.80		M	11.9	HS	42	L	5	66	2.5	3			LEH
2005 09 07.80		M	13.4	GA	41	L	4	113	1	2/			SHU

Comet 169P/NEAT

DATE (UT)	N	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
2005 08 02.95		I	14.9	HN	31.0	J	6	155		9			DIJ
2005 08 02.95		I	15.0	HN	31.0	J	6	155		9			BOU
2005 09 14.19		S	10.3	TK	20.3	T	10	100	3	2/			GON05
2005 10 07.20		S	12.3	TK	20.3	T	10	133	1.5	2			GON05
2005 10 24.82		S	[12.4	AU	40.0	L	4	144	! 0.9				YOS04

Comet C/2001 Q4 (NEAT)

DATE (UT)	N	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
2004 05 12.83		B	3.5	TI	6	R		20	18	6	1.25	70	DUB01
2004 05 13.84		B	3.4	TI	6	R		20	19	6	1.7	90	DUB01
2004 05 14.83		B	3.8	TI	6	R		20	17	6	0.95	110	DUB01
2004 05 15.82		B	4.2	TI	6	R		20	15	6			DUB01

Comet C/2001 Q4 (NEAT) [cont.]

DATE (UT)	N	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
2004 05 16.81		S	4.4	TI	3.0	B		6	15	5			DID01
2004 05 18.85		S	4.6	TI	3.0	B		6	15	5			DID01
2004 05 20.83		B	5.0	TI	6	R		20	13	5			DUB01
2004 05 22.86		S	5.2	TI	6	R	5	20	12	5		87	DID01
2004 05 26.86		B	5.2	TI	6	R		20	14	4			DUB01
2004 05 26.88		S	5.6	TI	6	R	5	20	10	4			DID01
2004 05 31.85		S	6.0	TI	5	R	5	15	11	5	0.4	84	DID01
2004 06 01.85		B	5.4	TI	6	R		20	13	4		50	DUB01
2004 06 02.83		S	6.1	TI	5.0	B		15	10	5	0.4		DID01
2004 06 03.85		B	5.5	TI	6	R		20	13	4			DUB01
2004 06 04.84		S	6.3	TI	5.0	B		15	9	5	0.4		DID01
2004 06 05.87		B	5.6	TI	6	R		20	13	4			DUB01
2004 06 06.89		S	6.3	TI	5.0	B		15	9	5	0.4		DID01
2004 06 08.89		S	6.5	TI	6	R	5	20	8	4			DID01
2004 06 09.85		S	6.4	TI	6	R	5	20	8	4			DID01
2004 06 11.87		B	6.8	TI	6	R		20	12	4			DUB01
2004 06 14.87		S	6.9	TI	6	R	5	20	9	3			DID01
2004 06 15.87		B	7.0	TI	6	R		20	12	4			DUB01
2004 06 17.86		B	7.1	TI	6	R		20	12	5			DUB01
2004 06 17.86		S	7.1	TI	6	R	5	20	10	3			DID01
2004 06 20.85		S	7.2	TI	6	R	5	20	12	3			DID01
2004 07 09.85		S	8.2	TI	6	R	5	20	12	3			DID01
2004 07 15.95		S	8.2	TI	6	R	5	20	9	3			DID01
2004 07 16.91		S	8.2	TI	6	R	5	20	8	3			DID01
2004 07 18.87		B	7.7	TI	6	R		20	9	3			DUB01
2004 07 19.87		B	7.8	TI	6	R		20	9	3			DUB01
2004 07 20.87		B	7.9	TI	6	R		20	9	3			DUB01
2004 07 20.92		S	9.0	TI	7.5	R	8	38	8	3			DID01
2004 07 21.87		B	8.1	TI	6	R		20	8	3			DUB01
2004 07 21.89		S	9.4	TI	7.5	R	8	38	8	3			DID01
2004 07 22.85		B	8.2	TI	6	R		20	8	3			DUB01
2004 07 23.85		B	8.3	TI	6	R		20	8	3			DUB01
2004 07 23.92		S	9.7	TI	7.5	R	8	38	5	3			DID01
2004 07 24.87		B	8.4	TI	6	R		20	8	2			DUB01
2004 07 25.87		B	8.4	TI	6	R		20	7	2			DUB01
2004 07 26.87		B	8.4	TI	6	R		20	7	2			DUB01

Comet C/2003 K4 (LINEAR)

DATE (UT)	N	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
2004 07 17.87		B	7.2	TI	6	R		20	19	5			DUB01
2004 07 18.87		B	7.1	TI	6	R		20	18	5			DUB01
2004 07 19.87		B	7.1	TI	6	R		20	18	5			DUB01
2004 07 20.86		B	7.1	TI	6	R		20	19	4			DUB01
2004 07 21.87		B	7.1	TI	6	R		20	18	4			DUB01
2004 07 22.85		B	7.0	TI	6	R		20	18	4			DUB01
2004 07 23.85		B	6.9	TI	6	R		20	17	4			DUB01
2004 07 24.86		B	6.8	TI	6	R		20	18	3			DUB01
2004 07 25.87		B	6.8	TI	6	R		20	18	3			DUB01
2004 07 26.87		B	6.8	TI	6	R		20	18	3			DUB01
2004 07 27.86		B	6.8	TI	6	R		20	18	3			DUB01
2005 09 03.18		S	12.3	TK	20.3	T	10	160	0.7	3			GON05
2005 09 30.14		S	12.8	TK	20.3	T	10	133	0.7	4			GON05
2005 10 08.77		S	12.8	AU	25.4	L	4	113	1.1	3			YOS02
2005 10 24.63		S	13.1	AU	40.0	L	4	144	1.6	4/			YOS04

Comet C/2003 WT_42 (LINEAR)

DATE (UT)	N	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
2005 10 24.79		S	13.5	TA	40.0	L	4	257	0.5	5			YOS04

Comet C/2004 B1 (LINEAR)

DATE (UT)	N	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
2005 10 21.44		S	12.6	GA	25.4	L	4	71					SEA
2005 10 22.47		S	12.7	GA	25.4	L	4	71	1.6	2			SEA

Comet C/2004 Q2 (Machholz)

DATE (UT)	N	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
2005 01 05.90		B	3.9	TI	6	R		20	19	3			DUB01
2005 01 08.90		B	3.9	TI	6	R		20	20	3			DUB01
2005 01 09.90		B	3.8	TI	6	R		20	21	3			DUB01
2005 01 16.89		B	4.0	TI	6	R		20	22	3			DUB01
2005 01 17.90		B	4.1	TI	6	R		20	20	5			DUB01
2005 02 05.90		B	5.3	TI	6	R		20	16	3			DUB01
2005 02 06.75		B	5.3	TI	6	R		20	17	4		50	DUB01
2005 02 07.85		B	5.4	TI	6	R		20	16	3			DUB01
2005 02 10.77		B	5.5	TI	6	R		20	15	4		80	DUB01
2005 03 03.83		B	6.5	TI	6	R		20	9	3			DUB01
2005 06 27.90		M	10.2	TT	10	B	4	25	4	3/			LEH
2005 06 28.90		S	10.5	TK	15	L	6	45	3.8	1			URB01
2005 06 28.91		M	10.2	TT	10	B	4	25	4	3			LEH
2005 07 02.90		S	10.7	TK	10	B		25	2	3			URB01
2005 07 03.88		S	10.7	TK	10	B		25	2	3/			URB01
2005 07 07.95		S	10.9	TK	10	B		25	2	2/			URB01
2005 07 14.95		S	11.1	TK	15	L	6	45	3	3			URB01
2005 07 15.96		S	11.2	TK	15	L	6	45	2.7	3			URB01
2005 07 26.53	x	S	11.9	TK	25.4	L	4	46	2.2	2			YOS02
2005 08 02.88		S	12.5	HS	30	L	5	180	0.7	3			NEV
2005 08 02.92		S	11.9	AU	31.0	J	6	89	1.5	1			BOU
2005 08 02.92		S	12.4	AU	31.0	J	6	89	1.5	1			DIJ
2005 08 02.97		S	11.1	TK	20.3	T	10	100	2.5	4			GON05
2005 08 03.93		S	11.2	NP	25.5	L	5	60	2	2/			MAR02
2005 08 04.92		S	11.3	NP	25.5	L	5	60	2	2			MAR02
2005 08 05.51		S	11.4	TJ	40.0	L	4	144	1.3	2/			YOS04
2005 08 05.91		S	11.9	AU	31.0	J	6	89	2	1/			BOU
2005 08 05.97		S	11.1	NP	32	L	5	75	2	2/			MAR02
2005 08 06.91		S	11.8	TI	23.5	T	10	94	3	2			LAB02
2005 08 08.89		S	12.0	HS	27.0	L	6	120	1.5	3			TOT03
2005 08 28.92		S	11.5	TK	20.3	T	10	133	2	3			GON05
2005 08 30.82		M	12.2	HS	42	L	5	81	2	3			LEH
2005 09 01.82		M	12.0	HS	42	L	5	81	2	3			LEH
2005 09 03.84		S	12.4	TI	23.5	T	10	188	2	2			LAB02
2005 09 03.85		S	12.6	AU	31.0	J	6	109	1.6	1/			BOU
2005 09 03.86		S	12.5	AU	31.0	J	6	109	3	1/			DIJ
2005 09 03.87		S	13.0	NP	44.5	L	5	100	2	2			MAR02
2005 09 03.88		S	12.8	NP	44.5	L	5	100	1	3			SAN04
2005 09 05.81		M	12.4	HS	42	L	5	81	2	3			LEH
2005 09 06.81		M	12.3	HS	42	L	5	81	2	3			LEH

Comet C/2005 A1 (LINEAR)

DATE (UT)	N	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
2005 07 15.02		S	11.2	TK	15	L	6	61	2.0	3			URB01
2005 07 16.03		S	11.2	TK	15	L	6	45	3.5	3/			URB01
2005 08 02.06		S	11.8	TK	20.3	T	10	100	2	4			GON05
2005 08 02.90		S	11.7	TK	30	L	5	60	1.5	2			NEV
2005 08 02.99		S	11.6	AU	31.0	J	6	89	2.2	2/			BOU
2005 08 03.00		S	11.4	AU	31.0	J	6	89	2.4	3/			DIJ
2005 08 03.92		M	12.8	TJ	41	L	4	89	1	3			SHU
2005 08 03.99		S	11.2	NP	25.5	L	5	60	2	2			MAR02
2005 08 04.73		S	11.6	TJ	40.0	L	4	144	1.8	1/			YOS04
2005 08 04.99		S	11.2	NP	25.5	L	5	60	2	2/			MAR02
2005 08 05.69		S	12.3	AU	40.0	L	4	144	1.2	4			YOS04
2005 08 05.76	x	S	11.8	TJ	32.0	L	5	87	1.2	3			NAG08
2005 08 05.99		S	11.8	AU	31.0	J	6	72	2.0	2/			BOU
2005 08 06.01		M	11.5	NP	32	L	5	75	2	3			MAR02
2005 08 06.02		M	11.9	NP	32	L	5	75	1.5	3			SAN04

Comet C/2005 A1 (LINEAR) [cont.]

DATE (UT)	N	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
2005 08 06.76		S	12.5	AU	40.0	L	4	144	1.2	3/			YOS04
2005 08 07.00		S	12.2	TI	23.5	T	10	94	2	2			LAB02
2005 08 08.94		S	12.0	HA	27.0	L	6	120	1.5	2			TOT03
2005 08 12.91		S	12.3	HS	30	L	5	60	1.5	3			NEV
2005 08 12.96		S	12.1	HS	27.0	L	6	120	1.5	3			TOT03
2005 08 15.11		S	12.1	TK	20.3	T	10	100	1.5	3			GON05
2005 08 15.87		S	12.8	HS	30	L	5	100	1	2			NEV
2005 08 15.90		M	13.0	TJ	41	L	4	113	1.5	3			SHU
2005 08 16.83		M	13.3	TJ	41	L	4	89	1	3			SHU
2005 08 18.00		M	13.3	TJ	41	L	4	113	0.5	3/			SHU
2005 08 18.01		S	12.8	HS	30	L	5	100	1	3			NEV
2005 08 28.96		S	12.5	TK	20.3	T	10	133	1.0	3			GON05
2005 08 29.84		S	12.5	HS	30	L	5	60	1	3			NEV
2005 08 29.88		S	13.3	TJ	41	L	4	89	1	2/			SHU
2005 08 30.91		M	13.5	TJ	41	L	4	113	1	2/			SHU
2005 08 30.91		S	12.7	HS	44.0	L	5	156	0.8	4			HAS02
2005 08 30.93		S	13.3	HS	30	L	5	100	0.8	2			NEV
2005 08 30.96		M	12.1	HS	42	L	5	81	2	5			LEH
2005 09 01.00		S	13.2	HS	30	L	5	60	0.7	2			NEV
2005 09 01.96		M	12.4	HS	42	L	5	81	2	5			LEH
2005 09 03.66	x	M	13.8	HS	200	C	5	323	0.5				TSU02
2005 09 03.90		S	11.9	TI	23.5	T	10	188	3	2			LAB02
2005 09 03.91		S	12.1	AU	31.0	J	6	89	1.9	2/			DIJ
2005 09 03.91		S	12.3	AU	31.0	J	6	89	1.8	3			BOU
2005 09 04.86		S	12.7	HS	44.0	L	5	156	0.6	4			HAS02
2005 09 05.83		M	13.4	GA	41	L	4	89	1	2/			SHU
2005 09 05.96		M	12.4	HS	42	L	5	81	2	5			LEH
2005 09 06.88		M	13.0	HS	35	L	5	158	1.5	4/			HOR02
2005 09 06.96		M	12.5	HS	42	L	5	81	2	5			LEH
2005 09 07.86		M	13.6	GA	41	L	4	113	1	2/			SHU
2005 09 07.99		M	12.4	HS	42	L	5	81	2	5			LEH
2005 09 14.02		M	13.5	GA	41	L	4	113	1	2/			SHU
2005 09 26.90		S	13.0	HS	27.0	L	6	167	0.7	3			TOT03
2005 09 30.87		S	13.4	HS	27.0	L	6	167	0.6	3			TOT03
2005 10 01.92		S	13.5	NP	44.5	L	5	100	1	2			SAN04
2005 10 01.92		S	13.8	NP	44.5	L	5	100	0.75	0/			MAR02
2005 10 24.41		S	13.6	AU	40.0	L	4	144	0.9	2			YOS04
2005 10 25.56		S	13.5	AU	40.0	L	4	144	1.1	3			YOS04

Comet C/2005 B1 (Christensen)

DATE (UT)	N	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
2005 08 05.53		S	[14.0	TA	40.0	L	4	257	! 0.4				YOS04

Comet C/2005 E2 (McNaught)

DATE (UT)	N	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
2005 07 30.52		S	12.9	GA	25.4	L	4	114					SEA
2005 07 31.44		S	12.8	GA	25.4	L	4	114	0.7				SEA
2005 08 02.42		S	13.0	GA	25.4	L	4	71					SEA
2005 08 03.00		S	12.2	TK	20.3	T	10	133	0.8	4			GON05
2005 08 06.96		S	11.5	TI	23.5	T	10	94	2	2			LAB02
2005 08 22.42		S	12.7	GA	25.4	L	4	71	1				SEA
2005 08 23.41		S	12.6	GA	25.4	L	4	71	1				SEA
2005 08 24.40		S	12.6	GA	25.4	L	4	71					SEA
2005 08 25.41		S	12.6	GA	25.4	L	4	114	1				SEA
2005 08 26.42		S	12.5	GA	25.4	L	4	71					SEA
2005 08 28.89		S	11.8	TK	20.3	T	10	133	0.8	4			GON05
2005 09 02.90		S	11.5	TK	20.3	T	10	100	1.0	4			GON05
2005 09 03.85		S	10.9	TI	23.5	T	10	94	3	3			LAB02
2005 09 03.86		S	13.2	NP	44.5	L	5	100	0.75	4			MAR02
2005 09 03.87		S	13.3	NP	44.5	L	5	100	0.5	5			SAN04
2005 09 07.92		S	11.5	TK	20.3	T	10	133	1.0	4			GON05
2005 09 08.47		S	12.2	AU	40.0	L	4	144	0.9	7			YOS04
2005 09 08.89		S	11.4	TK	20.3	T	10	133	1.0	4			GON05

Comet C/2005 E2 (McNaught) [cont.]

DATE (UT)	N	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
2005 09 21.83		S	11.2	TK	20.3	T	10	100	1.0	5			GON05
2005 09 25.44		S	12.1	AU	32.0	L	5	182	1.1	5			NAG08
2005 09 25.49		S	12.3	AU	25.4	L	4	116	0.8	6			YOS02
2005 09 25.84		S	11.4	TK	20.3	T	10	133	1.0	4			GON05
2005 09 27.47		S	11.5	GA	25.4	L	4	71	0.7				SEA
2005 09 29.42		S	11.5	GA	25.4	L	4	71					SEA
2005 09 30.42		S	11.6	GA	25.4	L	4	114	0.7				SEA
2005 10 01.83		M	12.9	NP	44.5	L	5	100	0.75	3/			MAR02
2005 10 01.84		M	13.0	NP	44.5	L	5	100	1	4			SAN04
2005 10 02.82		S	11.7	TI	20	T	10	80	2	5			LAB02
2005 10 06.47		S	12.2	AU	25.4	L	4	113	0.9	6			YOS02
2005 10 21.43		S	11.9	GA	25.4	L	4	114					SEA
2005 10 22.44		S	11.9	AU	25.4	L	4	113	1.2	6			YOS02
2005 10 22.48		S	11.9	GA	25.4	L	4	71					SEA
2005 10 24.40		S	11.7	TJ	40.0	L	4	144	1.7	6			YOS04
2005 10 25.40		S	11.2	TJ	40.0	L	4	144	1.3	5			YOS04
2005 10 26.84		S	11.3	TK	20.3	T	10	133	1.2	4			GON05

Comet P/2005 JQ_5 (Catalina)

DATE (UT)	N	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
2005 08 05.76		S	10.5	TJ	40.0	L	4	144	2.0	1			YOS04
2005 08 06.78		S	[9.5	TJ	40.0	L	4	144	! 1.7				YOS04

Comet C/2005 K1 (Skiff)

DATE (UT)	N	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
2005 08 02.98		S	14.1	HN	31.0	J	6	155	0.6	3			BOU
2005 08 02.99		S	14.0	HN	31.0	J	6	155	0.7	3/			DIJ
2005 08 03.95		S	12.7	NP	25.5	L	5	60	0.75	2			MAR02
2005 08 05.54		S	14.1	HS	40.0	L	4	257	0.5	3			YOS04
2005 08 05.93		S	14.0	HN	31.0	J	6	155	0.5	4			BOU
2005 08 06.96		S	12.3	TA	23.5	T	10	94	2	2			LAB02
2005 08 28.87		S	14.4	HS	44.0	L	5	156	0.4	4			HAS02
2005 08 30.84		B	14.0	HS	42	L	5	81	0.8	4			LEH
2005 09 01.84		B	14.3	HS	42	L	5	81	0.7	4			LEH
2005 09 05.84		B	14.1	HS	42	L	5	162	0.8	4			LEH
2005 09 06.84		B	14.1	HS	42	L	5	162	0.7	4			LEH
2005 09 07.88		B	14.3	HS	42	L	5	162	0.7	4			LEH

Comet P/2005 K3 (McNaught)

DATE (UT)	N	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
2005 08 05.72		S	13.9	HS	40.0	L	4	257	0.5	4			YOS04
2005 08 29.99		S	13.7	HS	44.0	L	5	156	0.4	4			HAS02
2005 09 03.96	a	S	13.7	HN	31.0	J	6	155	0.5	5/			BOU
2005 09 03.97	a	S	13.7	HN	31.0	J	6	155	0.6	5			DIJ
2005 10 24.65		S	[13.8	TA	40.0	L	4	257	! 0.7				YOS04

Comet C/2005 N1 (Juels-Holvorcem)

DATE (UT)	N	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
2005 07 04.04		S	[12.0	HS	40.5	L	4	128	! 1.0				SAR02
2005 07 15.00		S	11.6	TK	15	L	6	61	2.5	3/			URB01
2005 07 16.00		S	11.7	TK	15	L	6	61	2.9	3/			URB01
2005 08 02.12		S	11.6	TK	20.3	T	10	100	1.5	3			GON05
2005 08 02.93		S	11.3	TK	30	L	5	60	1	3			NEV
2005 08 02.95		M	12.0	TJ	41	L	4	89	1.2	2/			SHU
2005 08 02.97		S	11.8	TA	31.0	J	6	89	1.3	3/			BOU
2005 08 02.97		S	11.9	TA	31.0	J	6	89	1.1	3			DIJ
2005 08 03.95		M	12.2	TJ	41	L	4	89	1	2/			SHU
2005 08 05.73		S	[10.1	TJ	40.0	L	4	144	! 1.6				YOS04
2005 08 05.95		S	11.7	TA	31.0	J	6	89	1.5	3			BOU
2005 08 07.11		S	12.0	TI	23.5	T	10	94	2	2			LAB02
2005 08 12.15		S	11.4	TK	20.3	T	10	160	1.5	3			GON05

Comet C/2005 N1 (Juels-Holvorcem) [cont.]

DATE (UT)	N	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
2005 08 15.15		S	11.4	TK	20.3	T	10	133	1.5	4			GON05
2005 08 15.96		S	11.3	TK	30	L	5	60	1.5	3			NEV
2005 08 15.99		M	11.0	TJ	41	L	4	89	1	3/			SHU
2005 08 16.99		M	11.4	TJ	41	L	4	89	1.4	3/			SHU
2005 08 17.99		M	12.0:	TJ	41	L	4	89	1.2	3/			SHU
2005 08 18.00		S	11.5	TK	30	L	5	60	1.5	3			NEV
2005 08 29.83		S	11.8	TK	30	L	5	60	1.3	3			NEV
2005 08 29.88		S	11.6	TA	25.4	J	6	125	1.5	4			BOU
2005 08 29.89		S	11.8	TA	25.4	J	6	125	1.2	2/			DIJ
2005 08 30.95		S	11.2	TK	30	L	5	60	2	3			NEV
2005 08 31.03		M	11.9	TJ	41	L	4	89	1	3			SHU
2005 09 01.01		S	11.1	TK	30	L	5	60	3	3			NEV
2005 09 02.96		S	11.7	TK	30	L	5	60	1.5	2			NEV
2005 09 03.16		S	11.3	TK	20.3	T	10	77	2.0	3			GON05
2005 09 03.84		S	11.5	TA	31.0	J	6	89	1	2/			DIJ
2005 09 03.84		S	11.5	TA	31.0	J	6	89	1.8	4			BOU
2005 09 07.05		S	11.7	TK	30	L	5	60	1.5	2			NEV
2005 09 08.03		M	13.2	GA	41	L	4	89	1	2/			SHU
2005 09 08.85		S	11.2	TK	20.3	T	10	77	2	3			GON05
2005 09 11.81	&	S	11.7	TA	25.4	L	4	116	1.0	3			YOS02
2005 09 14.07		M	12.5	TJ	41	L	4	89	1.2	3			SHU
2005 09 14.18		S	11.3	TK	20.3	T	10	100	2.2	3			GON05
2005 09 30.20		S	11.5	TK	20.3	T	10	100	2	3			GON05
2005 10 07.21		S	11.8	TK	20.3	T	10	133	1.5	3			GON05

Comet C/2005 P3 (SWAN)

DATE (UT)	N	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
2005 08 28.84		S	10.0	TK	10.0	R	5	20	3.7	3			HAS02
2005 08 28.86		S	9.8	TK	20.3	T	10	77	2.5	4			GON05
2005 08 28.86		S	10.1	TK	25.4	J	6	58	1.8	3/			BOU
2005 08 28.87		S	9.6	TK	30.5	L	5	58	3.0	4			GIL01
2005 08 29.45	x	S	11 :	TK	45.7	L	4	68	2	5			MUR02
2005 08 29.80		M	10.4	TK	30	L	5	60	3	4			NEV
2005 08 29.87		S	9.8	TK	25.4	J	6	58	2.3	3/			DIJ
2005 08 29.87		S	10.0	TK	20.3	T	10	77	2.5	4			GON05
2005 08 29.87		S	10.0	TK	25.4	J	6	58	2.4	3/			BOU
2005 08 29.88		S	9.7	TK	10.0	B		25	3	3			GON05
2005 08 29.88		S	9.9	TK	30.5	L	5	72	2.5	4			GIL01
2005 08 30.79		S	10.5	TK	30	L	5	60	3	3			NEV
2005 08 31.45	x	S	10.9	TK	45.7	L	4	68	3.6	4			MUR02
2005 08 31.80		S	11.6	TK	30	L	5	60	2.5	3			NEV
2005 08 31.86		S	10.0	TK	25.4	J	6	58	1.9	3			DIJ
2005 08 31.86		S	10.1	TK	25.4	J	6	58	2.5	3/			BOU
2005 09 02.85		S	9.8	TK	10.0	B		25	3	3			GON05
2005 09 02.86		S	10.1	TK	20.3	T	10	77	2.5	3			GON05
2005 09 03.83		S	11.2	TI	23.5	T	10	94	2	2			LAB02
2005 09 03.86		S	10.3	TK	31.0	J	6	58	2.8	3/			BOU
2005 09 03.87		S	10.3	TK	31.0	J	6	58	1.9	3			DIJ
2005 09 03.87		S	10.4	TK	30.5	L	5	96	2.0	3			GIL01
2005 09 04.84		S	11.2	HS	32.0	L		72	1.0	3			PIL01
2005 09 05.86		S	10.8	TK	25.4	J	6	58	2.5	2			BOU
2005 09 07.04		S	12.4	HS	30	L	5	60	2	1			NEV
2005 09 07.86		S	11.2	TK	20.3	T	10	77	2.0	3			GON05
2005 09 08.07		M	12.5	TJ	41	L	4	89	1.5	3			SHU
2005 09 08.44		S	10.9	TJ	40.0	L	4	75	3.0	2			YOS04
2005 09 08.71		S	11.5	HS	27.0	L	6	83	1.3	3			TOT03
2005 09 08.87		S	11.1	TK	20.3	T	10	77	2.0	3			GON05
2005 09 14.08		M	12.6	GA	41	L	4	89	1	3			SHU
2005 09 14.17		S	11.6	TK	20.3	T	10	100	2	2			GON05
2005 09 21.84		S	12.2	TK	20.3	T	10	133	1.5	2			GON05
2005 09 23.79		S	11.0	HS	32.0	L		72	3.0	1			PIL01
2005 10 01.99		S	12.0	TI	20	T	10	80	1	3			LAB02
2005 10 02.81		S	12.1	TI	20	T	10	80	1	3			LAB02
2005 10 24.78		S	13.2	TA	40.0	L	4	144	1.3	0/			YOS04

Comet P/2005 R2 (Van Ness)

DATE (UT)	N	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
2005 09 25.85		S	13.6	HS	44.0	L	5	156	0.4	4			HAS02
2005 10 01.93		S	13.8	NP	44.5	L	5	100	0.5	2			MAR02
2005 10 01.94		S	13.5	NP	44.5	L	5	100	0.5	3			SAN04
2005 10 07.18		S	13.3	TK	20.3	T	10	133	0.5	5			GON05
2005 10 24.60		S	12.8	TA	40.0	L	4	144	1.2	6			YOS04
2005 10 25.59		S	12.8	TA	40.0	L	4	144	1.3	4			YOS04

Comet C/2005 T4 (SWAN)

DATE (UT)	N	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
2005 10 24.39		S	12.6	AU	40.0	L	4	144	1.5	3			YOS04
2005 10 26.80		S	12.0	TK	20.3	T	10	100	2	3			GON05

◇ ◇ ◇

Non-Visual Data (new format)

TABULATED NON-VISUAL DATA

The new format for non-visual data was introduced in the October 2001 issue of the *ICQ*, chiefly to help researchers make more sense of comet photometry obtained with CCD cameras, to determine what effects various instrumental factors play (spectral responses, exposure times, photometric aperture sizes, etc.). As described in that issue, almost all of the new information is added to the original observation records in columns 81-129, thereby leaving the first 80 columns essentially unchanged (except that in the "coma-diameter" column, true coma diameters are now given without exception in the new format; the old format allowed CCD users to put instead an aperture size in the "coma-diameter" column, but this is now allowed for in columns 87-93 of the new-format records). See also page 208 of the July 2002 issue.

Most of the columns below are as for the visual data (described on page 267 of this issue). While electronic magnitudes *can* be submitted to 0.01 magnitude, for many reasons it is highly advised to continue giving total comet magnitudes only to 0.1 mag. Similarly, it is advised to continue giving all times to 0.01 day, as 0.001 day is usually unnecessary for cometary photometry.

The headings for the tabulated data are as follows: The date (UT), notes, magnitude method (including filters for CCDs, and "P" for photographs), magnitude, reference, instrument aperture, instrument type, instrument *f*-ratio, exposure time, coma diameter, degree of condensation, tail length and position angle, and observer are all as described for the visual tabulation. The column headed "`APERTUR`" gives the photometric aperture, preceded by "`S`" for square aperture and "`C`" for circular aperture, and followed by "`d`" for degrees, "`m`" for arcmin, and "`s`" for arcsec. The column "`Chp`" contains the 3-character code for the computer chip, given to indicate spectral response of the CCD camera. This column will also be used to indicate photographic emulsion when such information is provided for photographic photometry. The column "`Sfw`" contains the 3-character code for the software used to actually perform the photometric measures (not solely to extract comparison-star magnitudes). A lower-case "a" between these two columns indicates an anti-blooming CCD. The column headed "`C`" gives a number as follows: 0 = no correction; 1 = correction for bias (bias subtracted); 2 = flat-field corrected (flat-fielded); 3 = 1 + 2; 4 = dark-subtracted (and bias-subtracted) 5 = 2 + 4. The column headed "`P`" includes a `P` if the images used to measure the photometry were also measured for astrometry *and* those astrometric measures were published in the *Minor Planet Circulars* (meaning they were refereed); a `U` in this column indicates that the respective astrometric was sent to the MPC for publication but that either (a) they are unpublished at the time of reporting the photometry or (b) the observer is unaware of the publication status; a blank in this column indicates that no astrometry was measured. The 3-character CCD-camera code is listed under "`Cam`".

◇ ◇ ◇

Comet 9P/Tempel

DATE (UT)	n M	MAG.	RF	AP. T	f/	EXP.	COMA	DC	TAIL	PA	APERTUR	Chp Sfw	C	P	Cam	OBS.
2005 07 27.46	axC	12.7	HV	35.0C	10	a 60	1.0	5			S 1.47m	KAIaSI4	5		ST2	TSU02
2005 09 01.45	axC	14.6	HV	35.0C	10	a450	0.6	4			S 0.68m	KAIaSI4	5		ST2	TSU02
2005 09 08.45	axC	12.5	HV	35.0C	10	a720	0.5	3			S 0.78m	KAIaSI4	5		ST2	TSU02
2005 10 01.41	axC	13.9	HV	35.0C	10	a 90	0.7	4			S 1.18m	KAIaSI4	5		ST2	TSU02
2005 10 20.40	axC	15.9	HV	35.0C	10	a120	0.2				S 0.25m	KAIaSI4	5		ST2	TSU02

Comet 10P/Tempel

```
DATE (UT)     n M MAG. RF  AP. T f/ EXP.  COMA  DC  TAIL   PA APERTUR Chp Sfw C P Cam  OBS.
2005 09 09.76 sxC 17.8 TJ  25.0L  5 a120   0.2                 S 0.2 m K42 SI4 5 U SE7  OHS
```

Comet 21P/Giacobini-Zinner

```
DATE (UT)     n M MAG. RF  AP. T f/ EXP.  COMA  DC  TAIL   PA APERTUR Chp Sfw C P Cam  OBS.
2005 07 31.81 axC 13.0 HV  35.0C 10 a 60   0.4  4              S 1.29m KAIaSI4 5   ST2  TSU02
2005 08 05.77 x C 12.6 TJ  25.0L  5 a120   1.0                 S 1.0 m K42 SI5 5 U SE7  OHS
2005 10 01.82 axC 14.2 HV  35.0C 10 a 90   0.4  5  > 4   m270 S 0.82m KAIaSI4 5   ST2  TSU02
```

Comet 29P/Schwassmann-Wachmann

```
DATE (UT)     n M MAG. RF  AP. T f/ EXP.  COMA  DC  TAIL   PA APERTUR Chp Sfw C P Cam  OBS.
2005 08 29.66 x C 14.5 GA  15.0L  6 a240   0.6                 S 1.5 m K26 SI5 5   ST9  YOS02
2005 09 09.63 sxC 14.8 TJ  25.0L  5 a120   0.6                 S 0.6 m K42 SI4 5 U SE7  OHS
2005 10 08.77 axC 13.8 GA  15.0L  6 a240   1.6                 S 1.6 m K26 SI5 5   ST9  YOS02
```

Comet 37P/Forbes

```
DATE (UT)     n M MAG. RF  AP. T f/ EXP.  COMA  DC  TAIL   PA APERTUR Chp Sfw C P Cam  OBS.
2005 08 03.50 axC 12.9 HV  35.0C 10 a120   0.9  5              S 1.00m KAIaSI4 5   ST2  TSU02
2005 08 10.55 x C 13.3 GA  15.0L  6 a 60   0.6                 S 0.6 m K26 SI5 5   ST9  YOS02
2005 09 01.53 axC 14.1 HV  35.0C 10 a360   0.4  4              S 0.53m KAIaSI4 5   ST2  TSU02
2005 09 08.48 axC 14.6 HV  35.0C 10 a120   0.5  5              S 0.76m KAIaSI4 5   ST2  TSU02
2005 09 23.45 axC 15.6 HV  35.0C 10 a480   0.3  4              S 0.52m KAIaSI4 5   ST2  TSU02
2005 10 19.44 axC 15.7 HV  35.0C 10 a810   0.3  3              S 0.54m KAIaSI4 5   ST2  TSU02
```

Comet 65P/Gunn

```
DATE (UT)     n M MAG. RF  AP. T f/ EXP.  COMA  DC  TAIL   PA APERTUR Chp Sfw C P Cam  OBS.
2005 09 09.78 sxC 17.5 TJ  25.0L  5 a240   0.3                 S 0.3 m K42 SI5 5 U SE7  OHS
```

Comet 74P/Smirnova-Chernykh

```
DATE (UT)     n M MAG. RF  AP. T f/ EXP.  COMA  DC  TAIL   PA APERTUR Chp Sfw C P Cam  OBS.
2005 09 09.68 sxC 18.0 TJ  25.0L  5 a240   0.3                 S 0.3 m K42 SI5 5 U SE7  OHS
```

Comet 101P/Chernykh

```
DATE (UT)     n M MAG. RF  AP. T f/ EXP.  COMA  DC  TAIL   PA APERTUR Chp Sfw C P Cam  OBS.
2005 08 05.71 x C 15.7 TJ  25.0L  5 a240   0.6     ?      243 S 0.6 m K42 SI5 5 U SE7  OHS
2005 09 01.60 axC 15.5 HV  35.0C 10 a480   0.4  5     1.5m254 S 0.79m KAIaSI4 5   ST2  TSU02
2005 09 09.74 sxC 15.1 TJ  25.0L  5 a240   0.6        0.7m245 S 0.6 m K42 SI5 5 U SE7  OHS
2005 09 30.63 axC 15.7 HV  35.0C 10 a120   0.3  5     0.8m255 S 0.95m KAIaSI4 5   ST2  TSU02
2005 10 01.63 axC 15.0 HV  35.0C 10 a 90   0.4  5     1.0m250 S 0.90m KAIaSI4 5   ST2  TSU02
```

Comet 107P/Wilson-Harrington

```
DATE (UT)     n M MAG. RF  AP. T f/ EXP.  COMA  DC  TAIL   PA APERTUR Chp Sfw C P Cam  OBS.
2005 07 31.80 axC 18.2 HV  35.0C 10 A200 < 0.2                 S 0.30m KAIaSI4 5   ST2  TSU02
2005 09 08.81 axC 19.1 HV  35.0C 10 A350 < 0.2                 S 0.17m KAIaSI4 5   ST2  TSU02
```

Comet 117P/Helin-Roman-Alu

```
DATE (UT)     n M MAG. RF  AP. T f/ EXP.  COMA  DC  TAIL   PA APERTUR Chp Sfw C P Cam  OBS.
2005 08 03.48 axC 13.6 HV  35.0C 10 a120   0.4  5     0.7m 95 S 0.95m KAIaSI4 5   ST2  TSU02
```

Comet 161P/Hartley-IRAS

```
DATE (UT)     n M MAG. RF  AP. T f/ EXP.  COMA  DC  TAIL   PA APERTUR Chp Sfw C P Cam  OBS.
2005 07 27.50 axC 11.2 HV  35.0C 10 a540   1.5  3              S 2.72m KAIaSI4 5   ST2  TSU02
2005 08 03.56 axC 12.5 HV  35.0C 10 A200   1.5  4     2.0m 25 S 2.94m KAIaSI4 5   ST2  TSU02
2005 08 27.44 axC 15.2 HV  35.0C 10 a 90   0.5  4              S 0.77m KAIaSI4 5   ST2  TSU02
2005 09 01.47 axC 15.4 HV  35.0C 10 A350   0.8  1              S 1.05m KAIaSI4 5   ST2  TSU02
2005 09 09.46 axC 16.3 HV  35.0C 10 A080   0.7  1              S 1.04m KAIaSI4 5   ST2  TSU02
```

Comet 168P/Hergenrother

```
DATE (UT)     n M MAG. RF  AP. T f/ EXP.  COMA  DC   TAIL  PA APERTUR Chp Sfw C P Cam   OBS.
2005 09 08.60 axC 15.3 HV  35.0C 10 a720   0.4  1             S 0.98m KAIaSI4 5   ST2  TSU02
2005 09 25.56 x C 15.7 GA  15.0L  6 a240   0.5        0.4m 65 S 0.5 m K26 SI5 5   ST9  YOS02
2005 09 30.51 axC 16.2 HV  35.0C 10 a240   0.4  4             S 0.70m KAIaSI4 5   ST2  TSU02
2005 10 01.51 axC 16.7 HV  35.0C 10 a900   0.3  4     0.5m 70 S 0.84m KAIaSI4 5   ST2  TSU02
2005 10 19.46 axC 16.3 HV  35.0C 10 a270   0.3  4             S 0.71m KAIaSI4 5   ST2  TSU02
```

Comet 169P/NEAT

```
DATE (UT)     n M MAG. RF  AP. T f/ EXP.  COMA  DC   TAIL  PA APERTUR Chp Sfw C P Cam   OBS.
2005 09 11.80   C 11.5 TJ  25.0L  5 a900   2.4        5.6m280 S 2.4 m K26 SI4 5*U ST9  KAD02
2005 09 12.79   C 11.7 TJ  25.0L  5 A080   2.1        5.9m279 S 2.1 m K26 SI4 5*U ST9  KAD02
2005 10 08.83 axC 14.9 GA  15.0L  6 a360   0.8                S 0.8 m K26 SI5 5   ST9  YOS02
```

Comet 170P/Christensen

```
DATE (UT)     n M MAG. RF  AP. T f/ EXP.  COMA  DC   TAIL  PA APERTUR Chp Sfw C P Cam   OBS.
2005 09 08.63 axC 18.6 HV  35.0C 10 B160   0.2  3             S 0.65m KAIaSI4 5   ST2  TSU02
2005 09 09.66 sxC 18.6 TJ  25.0L  5 a240   0.3                S 0.3 m K42 SI5 5 U SE7  OHS
```

Comet 171P/Spahr

```
DATE (UT)     n M MAG. RF  AP. T f/ EXP.  COMA  DC   TAIL  PA APERTUR Chp Sfw C P Cam   OBS.
2005 10 01.80 axC 16.9 HV  35.0C 10 a990   0.4  1             S 0.89m KAIaSI4 5   ST2  TSU02
```

Comet C/2002 VQ_94 (LINEAR)

```
DATE (UT)     n M MAG. RF  AP. T f/ EXP.  COMA  DC   TAIL  PA APERTUR Chp Sfw C P Cam   OBS.
2005 09 12.76 sxC 17.0 TJ  25.0L  5 a 30   0.3                S 0.3 m K42 SI5 5 U SE7  OHS
```

Comet C/2003 K4 (LINEAR)

```
DATE (UT)     n M MAG. RF  AP. T f/ EXP.  COMA  DC   TAIL  PA APERTUR Chp Sfw C P Cam   OBS.
2005 09 08.79 axC 13.8 HV  35.0C 10 a120   0.7  4             S 1.48m KAIaSI4 5   ST2  TSU02
2005 10 01.74 axC 13.6 HV  35.0C 10 a 90   1.8  5   > 5  m115 S 2.22m KAIaSI4 5   ST2  TSU02
2005 10 08.81 axC 13.4 GA  15.0L  6 a240   1.6       14  m111 S 1.6 m K26 SI5 5   ST9  YOS02
2005 10 12.73 axC 14.4 TJ  25.0L  5 a120   1.0                S 1.0 m K42 SI5 5 U SE7  OHS
```

Comet C/2003 T4 (LINEAR)

```
DATE (UT)     n M MAG. RF  AP. T f/ EXP.  COMA  DC   TAIL  PA APERTUR Chp Sfw C P Cam   OBS.
2005 10 01.84 axC 16.0:HV  35.0C 10 a420   0.2                S 0.41m KAIaSI4 5   ST2  TSU02
```

Comet C/2003 WT_42 (LINEAR)

```
DATE (UT)     n M MAG. RF  AP. T f/ EXP.  COMA  DC   TAIL  PA APERTUR Chp Sfw C P Cam   OBS.
2005 10 12.75 axC 15.6 TJ  25.0L  5 a120   0.5        0.9m288 S 0.5 m K42 SI5 5 U SE7  OHS
```

Comet C/2004 D1 (NEAT)

```
DATE (UT)     n M MAG. RF  AP. T f/ EXP.  COMA  DC   TAIL  PA APERTUR Chp Sfw C P Cam   OBS.
2005 09 12.77 sxC 17.1 TJ  25.0L  5 a 30   0.3                S 0.3 m K42 SI5 5 U SE7  OHS
```

Comet P/2004 F3 (NEAT)

```
DATE (UT)     n M MAG. RF  AP. T f/ EXP.  COMA  DC   TAIL  PA APERTUR Chp Sfw C P Cam   OBS.
2005 07 31.61 axC 14.1 HV  35.0C 10 a 90   0.4  5     0.8m270 S 1.10m KAIaSI4 5   ST2  TSU02
2005 08 10.60 sxC 15.2 GA  15.0L  6 a 60   0.6        0.4m250 S 0.6 m K26 SI5 5   ST9  YOS02
2005 09 09.48 axC 14.5 HV  35.0C 10 a120   0.5  5     1.0m288 S 1.02m KAIaSI4 5   ST2  TSU02
```

Comet C/2004 Q2 (Machholz)

```
DATE (UT)     n M MAG. RF  AP. T f/ EXP.  COMA  DC   TAIL  PA APERTUR Chp Sfw C P Cam   OBS.
2005 07 27.52 axC 12.4 HV  35.0C 10 a120   1.0  5             S 1.17m KAIaSI4 5   ST2  TSU02
2005 08 04.48 axC 12.0 HV  35.0C 10 a120   1.0  5             S 3.18m KAIaSI4 5   ST2  TSU02
2005 08 10.52 x C 13.2 TJ  15.0L  6 a 60   1.3                S 1.3 m K26 SI5 5   ST9  YOS02
```

Comet C/2004 Q2 (Machholz) [cont.]

DATE (UT)	n M	MAG.	RF	AP.	T	f/	EXP.	COMA	DC	TAIL	PA	APERTUR	Chp	Sfw	C	P	Cam	OBS.
2005 09 01.48	axC	14.7	HV	35.0	C	10	a810	0.3	4			S 0.75m	KAIa	SI4	5		ST2	TSU02
2005 09 09.43	axC	13.8	HV	35.0	C	10	a 90	0.5	5			S 1.24m	KAIa	SI4	5		ST2	TSU02
2005 09 25.43	axC	14.3	HV	35.0	C	10	a 90					S 0.94m	KAIa	SI4	5		ST2	TSU02
2005 09 25.45	x C	13.6	TJ	15.0	L	6	a240	0.9				S 0.9 m	K26	SI5	5		ST9	YOS02
2005 10 01.43	axC	14.4	HV	35.0	C	10	a270	0.5	5			S 1.24m	KAIa	SI4	5		ST2	TSU02
2005 10 19.39	axC	13.8	HV	35.0	C	10	a180	0.4	5			S 0.72m	KAIa	SI4	5		ST2	TSU02

Comet C/2005 A1 (LINEAR) [component not specified]

DATE (UT)	n M	MAG.	RF	AP.	T	f/	EXP.	COMA	DC	TAIL	PA	APERTUR	Chp	Sfw	C	P	Cam	OBS.
2005 08 05.67	sxC	13.0	TJ	25.0	L	5	a120	1.1		1.3m	213	S 1.1 m	K42	SI5	5	U	SE7	OHS

Comet C/2005 A1 (LINEAR) [component A]

DATE (UT)	n M	MAG.	RF	AP.	T	f/	EXP.	COMA	DC	TAIL	PA	APERTUR	Chp	Sfw	C	P	Cam	OBS.
2005 08 29.59	x C	13.9	GA	15.0	L	6	a240	0.6		3.2m	194	S 0.6 m	K26	SI5	5		ST9	YOS02
2005 09 01.57	axC	14.0	HV	35.0	C	10	a120	0.4	5	1.5m	196	S 0.76m	KAIa	SI4	5		ST2	TSU02
2005 09 08.67	axC	14.2	HV	35.0	C	10	a120	0.6	5	> 5 m	179	S 0.87m	KAIa	SI4	5		ST2	TSU02
2005 09 25.59	x C	14.0	GA	15.0	L	6	a240	0.6		13 m	170	S 0.9 m	K26	SI5	5		ST9	YOS02
2005 09 30.60	axC	14.7	HV	35.0	C	10	a120	0.6	5			S 0.82m	KAIa	SI4	5		ST2	TSU02
2005 10 01.57	axC	14.7	HV	35.0	C	10	a120	0.5	5	5.5m	165	S 0.98m	KAIa	SI4	5		ST2	TSU02
2005 10 19.58	axC	15.4	HV	35.0	C	10	a 90	0.4	5			S 0.62m	KAIa	SI4	5		ST2	TSU02
2005 10 20.58	axC	15.3	HV	35.0	C	10	a 90	0.4	5			S 0.68m	KAIa	SI4	5		ST2	TSU02

Comet C/2005 A1 (LINEAR) [component B]

DATE (UT)	n M	MAG.	RF	AP.	T	f/	EXP.	COMA	DC	TAIL	PA	APERTUR	Chp	Sfw	C	P	Cam	OBS.
2005 09 01.57	axC	16.3	HV	35.0	C	10	a120	0.2	4			S 0.34m	KAIa	SI4	5		ST2	TSU02
2005 09 08.67	axC	17.3	HV	35.0	C	10	a120	0.2	2			S 0.31m	KAIa	SI4	5		ST2	TSU02
2005 10 01.57	axC	17.1	HV	35.0	C	10	a120	0.2	4			S 0.36m	KAIa	SI4	5		ST2	TSU02
2005 10 20.58	axC	17.1	HV	35.0	C	10	a 90	0.2	3			S 0.43m	KAIa	SI4	5		ST2	TSU02

Comet C/2005 E2 (McNaught)

DATE (UT)	n M	MAG.	RF	AP.	T	f/	EXP.	COMA	DC	TAIL	PA	APERTUR	Chp	Sfw	C	P	Cam	OBS.
2005 07 31.64	axC	12.9	HV	35.0	C	10	a 90	0.4	5	1.0m	270	S 0.81m	KAIa	SI4	5		ST2	TSU02
2005 08 10.59	x C	13.0	GA	15.0	L	6	a 60	0.7		0.6m	270	S 0.7 m	K26	SI5	5		ST9	YOS02
2005 09 09.50	axC	13.2	HV	35.0	C	10	a 90	0.5	6			S 0.82m	KAIa	SI4	5		ST2	TSU02
2005 09 25.51	x C	12.3	TJ	15.0	L	6	a240	0.9				S 0.9 m	K26	SI5	5		ST9	YOS02
2005 09 30.46	axC	12.7	HV	35.0	C	10	a 90	0.5	6			S 0.88m	KAIa	SI4	5		ST2	TSU02
2005 10 20.44	axC	12.7	HV	35.0	C	10	a 60	0.6	6			S 1.09m	KAIa	SI4	5		ST2	TSU02

Comet P/2005 JQ_5 (Catalina)

DATE (UT)	n M	MAG.	RF	AP.	T	f/	EXP.	COMA	DC	TAIL	PA	APERTUR	Chp	Sfw	C	P	Cam	OBS.
2005 06 09.38	H	15.85	LA	200	C	10	a 10					C 6.1 s	EEV	IRA			Dil	FIT02
2005 06 09.38	R	16.42	LA	200	C	10	a 10					C 6.1 s	EEV	IRA			Dil	FIT02
2005 06 09.38	V	16.82	LA	200	C	10	a 10					C 6.1 s	EEV	IRA			Dil	FIT02
2005 08 05.76	sxC	14.2	TJ	25.0	L	5	a120	0.8				S 0.8 m	K42	SI5	5	U	SE7	OHS

Comet C/2005 K1 (Skiff)

DATE (UT)	n M	MAG.	RF	AP.	T	f/	EXP.	COMA	DC	TAIL	PA	APERTUR	Chp	Sfw	C	P	Cam	OBS.
2005 07 31.55	axC	16.2	HV	35.0	C	10	A560	0.3	4	1.0m	340	S 0.84m	KAIa	SI4	5		ST2	TSU02
2005 08 10.57	x C	16.6	GA	15.0	L	6	a240	0.4		0.5m	320	S 0.4 m	K26	SI5	5		ST9	YOS02
2005 08 27.55	axC	16.5	HV	35.0	C	10	a360	0.3	4			S 0.56m	KAIa	SI4	5		ST2	TSU02
2005 09 01.54	axC	16.5	HV	35.0	C	10	a360	0.3	3			S 0.60m	KAIa	SI4	5		ST2	TSU02
2005 09 09.53	sxC	16.4	TJ	25.0	L	5	a120	0.3		0.5m	332	S 0.3 m	K42	SI5	5	U	SE7	OHS
2005 10 01.48	axC	17.6	HV	35.0	C	10	a960	0.3	4	0.8m	350	S 0.65m	KAIa	SI4	5		ST2	TSU02
2005 10 19.40	axC	16.7	HV	35.0	C	10	a270	0.3	4	1.0m	346	S 0.54m	KAIa	SI4	5		ST2	TSU02

Comet P/2005 K3 (McNaught)

DATE (UT)	n M	MAG.	RF	AP.	T	f/	EXP.	COMA	DC	TAIL	PA	APERTUR	Chp	Sfw	C	P	Cam	OBS.
2005 08 29.65	x C	15.6	GA	15.0	L	6	a240	0.4		1.1m	262	S 0.4 m	K26	SI5	5		ST9	YOS02

Comet P/2005 K3 (McNaught) [cont.]

```
DATE (UT)     n M MAG. RF  AP. T f/ EXP.  COMA  DC  TAIL  PA APERTUR Chp Sfw C P Cam   OBS.
2005 10 01.77 axC 14.9 HV  35.0C 10 a 90   0.3  5    4.0m254 S 0.59m KAIaSI4 5   ST2  TSU02
2005 10 12.71 axC 15.1 TJ  25.0L  5 a120   0.6       0.7m255 S 0.6 m K42 SI5 5 U SE7  OHS
```

Comet C/2005 L3 (McNaught)

```
DATE (UT)     n M MAG. RF  AP. T f/ EXP.  COMA  DC  TAIL  PA APERTUR Chp Sfw C P Cam   OBS.
2005 09 08.55 axC 16.7 HV  35.0C 10 A440   0.3  4            S 0.57m KAIaSI4 5   ST2  TSU02
```

Comet C/2005 N1 (Juels-Holvorcem)

```
DATE (UT)     n M MAG. RF  AP. T f/ EXP.  COMA  DC  TAIL  PA APERTUR Chp Sfw C P Cam   OBS.
2005 07 31.76 axC 13.2 HV  35.0C 10 a 90   0.8  5            S 1.00m KAIaSI4 5   ST2  TSU02
2005 08 05.75 sxC 13.5 TJ  25.0L  5 a120   1.0               S 1.0 m K42 SI5 5 U SE7  OHS
```

Comet P/2005 N3 (Larson)

```
DATE (UT)     n M MAG. RF  AP. T f/ EXP.  COMA  DC  TAIL  PA APERTUR Chp Sfw C P Cam   OBS.
2005 09 08.57 axC 18.9 HV  35.0C 10 A800   0.3  2            S 0.34m KAIaSI4 5   ST2  TSU02
```

Comet C/2005 N5 (Catalina)

```
DATE (UT)     n M MAG. RF  AP. T f/ EXP.  COMA  DC  TAIL  PA APERTUR Chp Sfw C P Cam   OBS.
2005 08 05.73 sxC 16.4 TJ  25.0L  5 a240   0.4               S 0.4 m K42 SI5 5 U SE7  OHS
2005 09 08.72 axC 17.1 HV  35.0C 10 a120   0.3  4            S 0.51m KAIaSI4 5   ST2  TSU02
2005 10 01.63 axC 16.3 HV  35.0C 10 a360   0.3  5            S 0.53m KAIaSI4 5   ST2  TSU02
```

Comet C/2005 P3 (SWAN)

```
DATE (UT)     n M MAG. RF  AP. T f/ EXP.  COMA  DC  TAIL  PA APERTUR Chp Sfw C P Cam   OBS.
2005 08 27.43 axC 10.6 HV  35.0C 10 a 60   0.8  4            S 2.24m KAIaSI4 5   ST2  TSU02
2005 09 08.42 axC 13.5 HV  35.0C 10 a720   0.6  2            S 1.67m KAIaSI4 5   ST2  TSU02
2005 09 12.79 sxC 13.2 TJ  25.0L  5 a 30   1.3               S 1.3 m K42 SI5 5 U SE7  OHS
```

Comet P/2005 R1 (NEAT)

```
DATE (UT)     n M MAG. RF  AP. T f/ EXP.  COMA  DC  TAIL  PA APERTUR Chp Sfw C P Cam   OBS.
2005 09 09.53 sxC 16.8 TJ  25.0L  5 a240   0.2               S 0.2 m K42 SI5 5 U SE7  OHS
2005 10 01.74 axC 16.9 HV  35.0C 10 a180   0.2  5    0.5m230 S 0.53m KAIaSI4 5   ST2  TSU02
```

Comet P/2005 R2 (Van Ness)

```
DATE (UT)     n M MAG. RF  AP. T f/ EXP.  COMA  DC  TAIL  PA APERTUR Chp Sfw C P Cam   OBS.
2005 09 12.65 sxC 16.5 TJ  25.0L  5 a 30   0.3               S 0.3 m K42 SI5 5 U SE7  OHS
2005 10 08.76 x C 13.6 GA  15.0L  6 a240   1.0       5.5m245 S 1.0 m K26 SI5 5   ST9  YOS02
```

Comet C/2005 T4 (SWAN)

```
DATE (UT)     n M MAG. RF  AP. T f/ EXP.  COMA  DC  TAIL  PA APERTUR Chp Sfw C P Cam   OBS.
2005 10 23.38 axC 13.0 HV  35.0C 10 a180   0.9  4            S 1.09m KAIaSI4 5   ST2  TSU02
```

Φ Φ Φ

2005 Edgar Wilson Awards

The 2005 Edgar Wilson Award for the discovery of comets (cf. *IAUC* 6936, 8372) was divided among the following two individuals: Roy A. Tucker, Tucson, AZ, U.S.A., for C/2004 Q1; and Donald Edward Machholz, Jr., Colfax, CA, U.S.A., for C/2004 Q2.

DESIGNATIONS OF RECENT COMETS

Listed below, for handy reference, are the last 30 comets (non-spacecraft) to have been given designations in the new system. The name, preceded by a star (⋆) if the comet was a new discovery (compared to a recovery from predictions of a previously-known short-period comet) or a # if a re-discovery of a 'lost' comet. (The 'P/' prefix for designations is used for new comets with orbital periods < 30 yr; otherwise, 'C/' is used.) Also tabulated below are such values as the orbital period (in years) for periodic comets, date of perihelion, T (month/date/year), and the perihelion distance (q, in AU). Four-digit numbers in the last column indicate the *IAU Circular* (4-digit number) containing the discovery/recovery or permanent-number announcement.

Comet P/2002 BV (Yeung) has been numbered 172P. [This list updates that in the July 2005 issue, p. 222.]

	New-Style Designation	P	T	q	*IAUC*
⋆	167P/2004 PY$_{42}$ (CINEOS)	64.8	4/24/01	11.8	8545
⋆	170P/2005 M1 (Christensen)	8.63	1/26/06	2.93	8547
⋆	P/2005 JD$_{108}$ (Catalina-NEAT)	16.4	8/4/05	4.03	8554
⋆	C/2005 N1 (Juels-Holvorcem)		8/22/05	1.13	8557
	168P/2005 N2 (Hergenrother)	6.92	11/2/05	1.43	8560
⋆	P/2005 N3 (Larson)	6.80	12/10/05	2.20	8560
⋆	C/2005 N4 (Catalina)		7/2/05	2.30	8568
⋆	C/2005 N5 (Catalina)		8/22/05	1.63	8568
⋆	169P/2002 EX$_{12}$ (NEAT)	4.20	9/17/05	0.61	8578
⋆	C/2005 O1 (NEAT)		5/17/05	3.59	8578
⋆	C/2005 O2 (Christensen)	115	9/8/05	3.33	8579
⋆	C/2005 P3 (SWAN)		8/9/05	0.53	8587
⋆	C/2005 Q1 (LINEAR)		8/25/05	6.4	8590
⋆	P/2005 Q4 (LINEAR)	9.4	9/28/05	1.75	8595
⋆	P/2005 R1 (NEAT)	12.9	10/8/05	2.05	8595
⋆	P/2005 R2 (Van Ness)	6.34	2/10/05	2.13	8597
⋆	P/2004 FY$_{140}$ (LINEAR)	11.0	8/7/04	4.11	8597
	171P/2005 R3 (Spahr)	6.62	9/3/05	1.73	8599
⋆	C/2005 R4 (LINEAR)		3/8/06	5.19	8601
⋆	P/2005 S2 (Skiff)	22.5	6/29/06	6.4	8606
⋆	P/2005 S3 (Read)	10.9	1/10/06	2.84	8608
⋆	C/2005 S4 (McNaught)		7/18/07	5.85	8609
	173P/2005 T1 (Mueller)	13.6	5/18/08	4.21	8613
⋆	P/2005 T2 (Christensen)	7.52	4/9/05	2.21	8614
⋆	P/2005 T3 (Read)	23.0	11/20/04	5.92	8614
⋆	C/2005 T4 (SWAN)		10/9/05	0.65	8619
⋆	P/2005 RV$_{25}$ (LONEOS-Christensen)	9.0	8/11/06	3.60	8620
⋆	P/2005 T5 (Broughton)	19.5	11/3/05	3.25	8621
⋆	P/2000 QJ$_{46}$ (LINEAR)	14.4	12/10/00	1.93	8622
⋆	P/2005 U1 (Read)	5.9	7/7/05	2.26	8624

Φ Φ Φ

INDEX TO THE INTERNATIONAL COMET QUARTERLY: Volumes 26-27

Vol. 26, No. 1 (Whole No. 129): January 2004, pages 1–54
Vol. 26, No. 2 (Whole No. 130): April 2004, pp. 55–112
Vol. 26, No. 3 (Whole No. 131): July 2004, pp. 113–182
Vol. 26, No. 4 (Whole No. 132): October 2004, pp. 183–241
Vol. 26, No. 4a (Special Issue): December 2004, pp. H1-H140
Vol. 27, No. 1 (Whole No. 133): January 2005, pages 1–84
Vol. 27, No. 2 (Whole No. 134): April 2005, pp. 85–138
Vol. 27, No. 3 (Whole No. 135): July 2005, pp. 139–222
Vol. 27, No. 4 (Whole No. 136): October 2005, pp. 223-281
Vol. 27, No. 4a (Special Issue): November 2005, pp. H1-H160

This index follows the style used in the previous indices, the most recent being for Volumes 23-25 (January 2004 issue, p. 53). References listed below indicate page number. For example, (**26**:118) indicates page 118 of Volume 26, which was in the July 2004 issue (ascertained from the listing above). (NOTE: descriptive information and tabulated data by observers under "Tabulation of Comet Observations" in each issue are not broken down by comet in this index). —D.W.E.G.

Various Items in Volumes 26-27, by topic and title:

Textual articles, letters, *etc.* — listed alphabetically by author (Volumes 26-27):

Φ Φ Φ